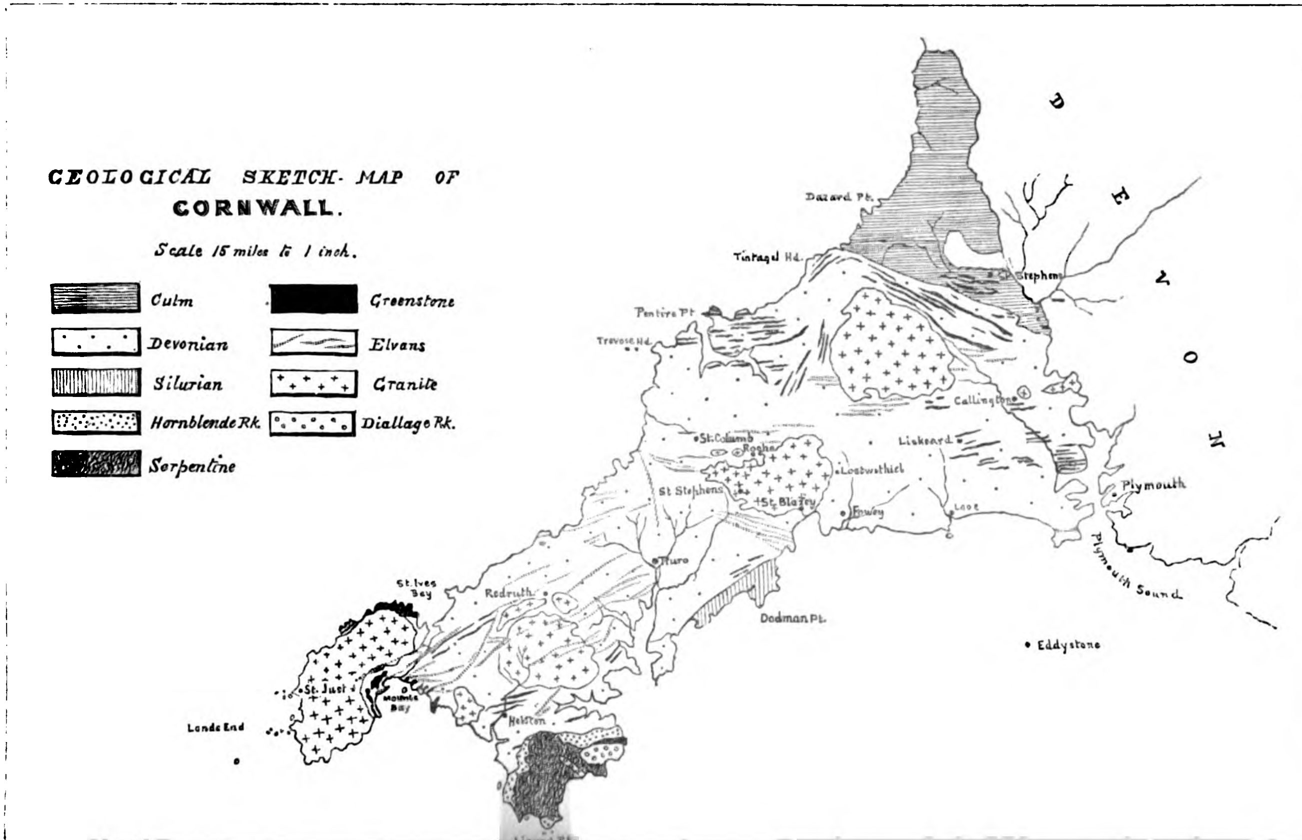
A TREATISE

ON

ORE DEPOSITS


GEOLOGICAL SKETCH-MAP OF
CORNWALL.
Scale 15 miles to 1 inch.
Culm
Devonian
Silurian
Hornblende Rk.
Serpentine
Greenstone
Elvans
Granite
Diallage Rk.
DEVON
Dazard Pt.
Tintagel Hd.
Pentire Pt.
Trevose Hd.
St. Stephens
Callington
Liskeard
St. Columb
Roche
Lostwithiel
St Stephens
St. Blazey
Fowey
Looe
Plymouth
Plymouth Sound
Eddystone
Truro
Dodman Pt.
St. Ives Bay
Redruth
St. Just
Mounts Bay
Helston
Lands End
Lizard Pt.

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PREFACE.

THE literature of metalliferous deposits, in the English language, is by no means inconsiderable. Numerous valuable disquisitions have at different times been published either as separate works or as communications to scientific journals, but the only general and systematic treatise on the subject which has appeared in English is a translation of Von Cotta's *Lehre von den Erzlagerstätten*, by Mr. Frederick Prime, published at New York in 1870.

Since that date much valuable information upon this subject has been accumulated, and the investigations of Daubrée, Daintree, Sandberger, and others have within the last few years thrown much additional light upon the genesis of metalliferous deposits.

The present work, which includes the results of the most important recent investigations, is divided into two parts. In the first, ore deposits in general are described and classified, while, in the second, examples are given from the principal mining regions of the old and the new world. In this portion of the work many remarkable metalliferous deposits of both ancient and recent formation are described, while, as a means of forming a standard of their comparative importance, copious statistics of production are furnished. Wherever exact information on this subject has been available, tabulated statistics of the yield of the principal ore-producing countries have been supplied. This appears to be the only way of accurately expressing the relative importance of different metalliferous regions, and care has been taken to collect information from trustworthy sources only.

During the preparation of a portion of the work I have had the assistance of Mr. B. H. Brough, Associate of the Royal School of Mines, and formerly student at the Mining School of Clausthal. For a period extending over several months, Mr. Brough was occupied in collecting statistical and other information from various foreign sources, and I am further indebted to him for numerous useful suggestions with regard to the arrangement of the matter, and for the careful attention which he has bestowed upon the work while passing through the press.

The greatest care has been taken to insure accuracy throughout the work, and the author hopes that but few mistakes will be found in it; although, in collecting such a large number of facts from so many different sources he cannot expect to have entirely escaped falling into error.

The Illustrations are from the pencil of Mr. Frank Rutley.

KENSINGTON, *July*, 1884.

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PART II.

ERRATA.

Page 68, line 10, *for* Algieria *read* Algeria.
,, 194, ,, 2, *for* Sedgewick *read* Sedgwick.
,, 222, last line but one, *for* Bailey *read* Baily.
,, 232, line 1 (*note*), *for* Algéria Annee, 1880, *read* Algérie, Année 1880.
,, 410, ,, 27, *for* Furahjelm *read* Furuhjelm.
,, 444, bottom line, *for* Mynwesen *read* Mijnwezen.
,, 550, line 8, *for* graphite *read* carbonized wood.

LIST OF ILLUSTRATIONS.

ORE DEPOSITS.

PART I.

ORE DEPOSITS IN GENERAL.

METALS which occur in a state of approximate purity are said to be *native*, and when two or more such metals are found in combination the mixture is called a *native alloy*. Usually the metals sought after by the miner are, however, not found in the native state, but are mineralized by uniting with various non-metallic bodies. In this way they combine with sulphur or chlorine, giving rise, respectively, to metallic sulphides or chlorides; with oxygen the metals form oxides, and with acids they yield salts, such as carbonates, sulphates and phosphates.

All natural combinations of a metal with such mineralizing substances are called *ores* when the proportion of metal which they contain, after suitable mechanical preparation, is sufficiently large to admit of their being advantageously treated by the metallurgist. Although perhaps not strictly correct, any material obtained by mining that contains a workable proportion of a metal is often called an ore, even if the whole of the metal be present in the native state.

Ores of the different metals are sometimes found in surface deposits, disseminated through igneous and sedimentary rocks, in more or less regularly stratified or bedded formations, in detached masses, and, above all, in *veins* of various descriptions. The non-metalliferous minerals forming part of the latter are known as the *matrix, gangue*, or *veinstone*. Metalliferous minerals are found in rocks of every geological age; but they occur most frequently in mountainous districts, and in the older rocks, especially near the junction of igneous rocks with those of sedimentary origin. They are also frequently met with in strata which have either been penetrated by eruptive dykes, or have been subjected to extensive metamorphic alteration. The ores of each of the different metals are, however, often restricted within certain geological horizons, beyond which they seldom occur in remunerative quantities.

Gold, platinum, and tin ore are found in alluvial detritus, in which they evidently were not formed by chemical action, but result from the disintegration of older deposits whose constituents have been removed and re-arranged by the mechanical agency of water.

The fragments constituting these superficial deposits are usually much water-worn, and the associated metals or metalliferous particles are mainly concentrated in particular areas, over which water has flowed with great activity. Metalliferous deposits of this kind are usually of comparatively recent date, and are generally not older than the Tertiary period.[1] Localities in which alluvial detritus is washed for gold are known as *placers*, but when tinstone is the ore sought after they are called *streamworks*.

The ores of iron and manganese are almost the only metalliferous minerals usually occurring in stratified beds, those of nearly all the other metals being obtained from some other variety of mineral deposit.

Although aluminium and magnesium are now regularly produced upon a small scale, they can scarcely be classed among metals derived from metalliferous ores, in the sense in which that term is usually understood. The same may be said of sodium, which is chiefly employed in the preparation of the two abovementioned metals.

Metalliferous deposits are found in such varying forms, and under such differing circumstances, that it might at first appear difficult to classify them in accordance with their characteristic peculiarities and modes of occurrence. A careful study of their

[1] Small quantities of gold were formerly collected near Bessèges, Département du Gard, France, by washing a coarse-grained quartzose conglomerate of Lower Carboniferous age.

origin, structure, and composition appears, however, to justify their division into the following groups:—

I. SUPERFICIAL.	*a.* Deposits formed by the mechanical action of water. *b.* Deposits resulting from chemical action.
II. STRATIFIED.	*a.* Deposits constituting the bulk of metalliferous beds formed by precipitation from aqueous solutions. *b.* Beds originally deposited from solution, but subsequently altered by metamorphism. *c.* Ores disseminated through sedimentary beds, in which they have been chemically deposited.
III. UNSTRATIFIED.	*a.* True veins. *b.* Segregated veins. *c.* Gash veins. *d.* Impregnations. *e.* Stockworks. *f.* Fahlbands. *g.* Contact deposits. *h.* Chambers or pockets.

SUPERFICIAL DEPOSITS.

a. DEPOSITS FORMED BY THE MECHANICAL ACTION OF WATER. —The most important superficial deposits of this class are those worked for gold and oxide of tin. These often consist of accumulations of sand and gravel formed on the banks of streams, by the action of whose waters the aggregation of metalliferous *débris* has been effected.

In other cases, superficial metalliferous deposits represent the beds of ancient rivers, and are frequently of great thickness and of large extent.

Surface deposits of iron ore sometimes belong to this class, but have more frequently been deposited *in situ* by chemical action.

Placers.—In the case of auriferous quartz, and of the ores of metals distributed through a valueless matrix, it is necessary, before the metalliferous portions can be separated, that the veinstone should be more or less finely crushed by suitable machinery. The pulverized material is afterwards subjected to the action of water, so set in motion as to allow the heavier particles, by obeying the laws of gravitation, to fall to the bottom, while the non-metalliferous matrix is carried off in suspension. All auriferous sands and gravels have, on the contrary, been already pulverized and concentrated by a natural process of a similar kind, and it consequently only remains for the miner to separate the valuable from the valueless material either by re-washing alone, or by re-washing assisted by the use of mercury.

The most remarkable and extensive accumulations of auriferous gravels are probably those of California, where they are frequently of very considerable thickness, and extend over areas of many square miles on the Pacific slope of the Sierra Nevada.[1] These, which are sometimes known as *blue gravels*, were formerly believed to be of marine origin, but are now recognised as materials brought down by the agency of currents of fresh water from the mountains high above them and deposited, either in the beds of ancient rivers, or in lake-like expansions of such streams. This deposition of auriferous detritus generally took place during the latter portion of the Pliocene epoch, as is proved by the remains of animals and plants which it encloses, although some of these would appear to exhibit certain Miocene relationships. This deposit of detritus was succeeded, throughout the whole extent of the Sierra, by an outbreak of volcanic activity, during which the auriferous drifts were, to a large extent, covered by deep accumulations of ash, pumice, and lapilli, which were finally overwhelmed by a general outpouring of lava. This capping of an almost indestructible material, sometimes above a hundred feet in thickness, has thus protected extensive areas of gravel which would otherwise have been swept away.

The most important chemical change which has taken place in these gravels subsequent to their deposition, is silicification, which becomes evident on examining the various organisms which are found embedded in them. The quantity of wood buried in these detrital masses is very large, and by far the greater proportion of the trees so found have been converted into opal. These tree trunks sometimes bear evidence of having been worn by the action of the currents which bore them along together with the stony detritus

[1] J. D. Whitney, "The Auriferous Gravels of the Sierra Nevada of California," *Memoirs of the Museum of Comparative Zoology at Harvard College*, vol. vi. 1880.

in which they finally became enclosed. In some cases, fragments of wood are met with which had been more or less completely converted into lignite previous to silicification. This partial conversion into lignite may often be observed in specimens in other parts of which direct silicification has taken place; so that the two ends of the same fragment may resemble, respectively, jet and opal. The transition from silicified wood to silicified lignite is, however, very gradual, although both often retain their original woody structure.

The following analyses of specimens of silicified wood and silicified lignite, made in duplicate by the author, will serve to show the difference in their respective compositions:—

	Silicified Wood. Sp. gr. = 2·04.		Silicified Lignite. Sp. gr. = 1·95.	
	I.	II.	I.	II.
Water	5·77	5·80	4·41	4·46
Silica	92·43	92·26	80·04	79·82
Alumina	trace.	trace.	trace.	trace.
Ferrous oxide	·90	·88	·92	·87
Lime	·12	·18	·16	·16
Potash	·41	·37	·37	·30
Soda	·20	·18	·20	·22
Carbonaceous matter, &c.	—	—	14·06	13·92
	99·83	99·67	100·16	99·75

Both specimens were obtained from the trunk of the same tree found in the auriferous drift under a volcanic capping, near Nevada city.

These results show that although all traces of organic matter have disappeared from the silicified wood, the silicified lignite still retains 14 per cent. of woody material. The gravels of which auriferous deposits are composed have in many instances become firmly consolidated by a siliceous cement, and cases in which large transparent crystals of quartz have formed in the cavities between contiguous pebbles, are by no means unknown.

In addition to bones and teeth of the mastodon and of other extinct mammals, human remains, together with various rude works of art, are stated, on trustworthy authority, to have been discovered in these gravels. The remains thus found are supposed to include the celebrated Calaveras skull, which is stated to have been taken from the auriferous gravel at a depth of above 120 feet from the surface, and beneath a capping of dense black lava.

Among the works of art may be mentioned several curious stone implements found in the gravels under Table Mountain in Tuolumne county, covered by 150 feet of lava. These include stone spear-heads, many inches in length, mortars cut out of granite, and various stone scoops and ladles with well-shaped handles. The evidence on this subject appears to be now fairly established, and would lead to the conclusion that man must have existed in California in Pliocene times, and that he was contemporaneous with the mastodon and other extinct animals.

The classification with "superficial deposits" of auriferous gravels which are not unfrequently covered by a flow of lava, might at first sight appear a misnomer; but a volcanic capping is by no means universal, and the uncovered beds of this age are of the greatest importance to the miner. They yield a very large proportion of the gold annually obtained in California, and are usually worked by the process known as hydraulic mining. This consists in attacking the bank of auriferous material with one or more jets of water issuing from nozzles, sometimes six inches in diameter, which are connected by a column of wrought-iron pipes with a reservoir from 200 to 400 feet above the level of the discharge. In this way an enormous mechanical force is obtained, and the bank, unless much consolidated by cement, is rapidly undermined and broken down. The water, with the disintegrated sand and gravel resulting from this operation, is conducted through large sluices provided with grooves or "riffles," into which mercury is introduced for the purpose of retaining the gold. This method of mining cannot, however, be applied except in localities where there is a proper fall for the sluice, and at the same time a sufficient depth below its outlet for the accumulation of the resulting rubbish or tailings. Every river flowing through the auriferous belt of the Sierra Nevada has acted as a natural sluice, the inequalities and the upturned slates of its bed taking the place of riffles for the retention of gold, derived not only from the immediate disintegration of auriferous outcrops, but also from the re-washing of older gravels. There will therefore be no difficulty in understanding the nature of the process by which a large amount of the precious metal has become concentrated within a comparatively limited space, and, consequently, that during the first two years after the discovery of gold in California, a vast majority of the miners were occupied on " river diggings." These naturally enriched accumulations having eventually become exhausted, it became necessary to attack the original more abundant, but poorer, gravels lying at greater elevations above the valleys; and in order to do this with advantage, a cheaper method of working than had hitherto been employed was required. This was supplied by the hydraulic system of mining, first introduced in 1852, and at the present time a considerable portion of the gold contributed by California is obtained from Pliocene gravels.

It is remarkable that the auriferous gravels of Victoria are of approximately the same geological age as those of California; they, however, more frequently than in the latter country represent the beds of ancient rivers once flowing through valleys which have subsequently been filled by the outpouring of volcanic matter. Victoria does not generally possess facilities for the employment of the hydraulic process, and the principal part of the placer gold found in that country is consequently obtained by mining beneath a capping of compact lava.

In consequence of the absence of marine Tertiary deposits in New South Wales, and the occurrence of a more complete series of strata in the Carboniferous formation, it is difficult to correlate precisely the gold deposits of that country with those of Victoria. It is, however, generally admitted that they occur in Tertiary strata, and are often of Pliocene age, although certain gravels which may be possibly Miocene are also sometimes auriferous.

Among surface deposits resulting from the mechanical action of water are those streaks of titaniferous iron sand, often found on sea beaches along coasts largely composed of certain igneous rocks. The disintegration of such rocks liberates crystals of magnetite and of titaniferous iron ore, and these minerals being heavier than the felspar, quartz, &c., with which they are associated, become concentrated by the action of the waves. Large accumulations of black sands occur along the shores of the Bay of Naples, at Taranaki in New Zealand, between Point Mendocino in California and the mouth of the Umpqua River in Oregon, and particularly in Canada on the north shore of the St. Lawrence, from the Moise River eastward. The ferruginous sands are here derived from the waste of the norite or labradorite rocks of the Upper Laurentian series, which are largely made up of labradorite and hypersthene, with magnetic and titaniferous iron ore, &c. At Mingan, Natasquan, and at several other points along the Labrador coast, iron sands occur under generally similar conditions. The production of cast-iron from these sands is rendered difficult by their extremely fine state of division, but they have sometimes been advantageously employed for the direct production of blooms in the open fire. The black sands on the coast of California are not unfrequently auriferous, and are sometimes washed for the gold which they afford.

Nearly the whole of the gold produced in the Russian empire is obtained from placer washings, vein-mining being exclusively confined to the Ural Mountains, and is even there carried on upon a very limited scale. The gold-bearing alluvium of the Ural is sometimes a heavy clay, while in other cases it is made up of water-worn fragments of auriferous quartz, chloritic and talcose schists, serpentine, greenstone, &c.

Remains of various extinct animals occur deep down in these gravels, usually in the vicinity of the bed-rock. They include bones of *Elephas primigenius*, *Bos aurochs*, and *Rhinoceros tichorhinus*, which are likewise found in the gravels of western Europe. Some of the auriferous gravels of the Ural repose upon a water-worn bed-rock of hard highly-inclined crystalline limestone, believed to be of Silurian age; in other cases they lie on a talc schist, or on a soft granitic rock containing pyrites and but little mica usually known as *beresite*. The two last-named rocks are traversed by veins of auriferous quartz.

Platinum generally occurs with gold in auriferous gravels, and is seldom found without that metal except at Tagilsk and Goroblagodatsk, in the Ural, where there is little or no gold. Platinum is obtained from placer diggings only, and has not been found to any considerable extent *in situ*, although grains of this metal are said to have been observed in the quartz of the mines of Beresovsk. In the districts in which platinum occurs unaccompanied by gold, the rocks in the neighbourhood of the deposits consist of serpentine and peridotite, while fragments of these rocks predominate in the sands and gravels. Chloritic and talcose schists, together with chrome iron ore, are to some extent present. From the constant occurrence of this metal in association with gravels mainly consisting of peridotite and serpentine, it is thought that platinum originally existed in the form of grains disseminated through these rocks. In addition to gold and chrome iron ore, platinum is often associated with iridium and iridosmine.

Streamworks.—The detrital tin ore of Cornwall may be grouped under the following heads:—

a. Tin ore forming a constituent of river gravels and sea-beaches actually in progress of formation. The tin ore of such formations usually occurs in angular or sub-angular particles.

b. That found in ancient stanniferous valley-gravels. These occur at all elevations up to about 700 feet, but are invariably in the immediate neighbourhood of considerably higher ground. Deposits belonging to this class were formerly very extensively worked, and have, in the aggregate, yielded large quantities of tin ore.

c. Pebbles and grains found in the "head" or angular *débris* constituting the overburden of the china-clay districts. This differs from the older quartz gravels of some parts of western Cornwall in being both coarser and more angular. Tin ore is also found disseminated through the soil in the vicinity of tin veins.

d. The pebbles and grains of tin ore found in the most ancient high-lying quartz gravels, such as those of St. Agnes Beacon.

Tin streaming, although upon a very restricted scale, is still carried on in Cornwall on some inconsiderable stanniferous deposits; but the deeper and more extensive valley-gravels, which were formerly so productive, may now be regarded as practically exhausted.

The sections laid open by the deeper streamworks were by no means of uniform interest, but those exposed in Par Valley, at Pentewan, and near the estuary of the Fal may be regarded as among the most important and instructive.

The Happy Union Streamwork, which has now been closed for more than forty years, was situated near the *débouchement* of the St. Austell valley at the port of Pentewan. Through this valley flows a stream of moderate dimensions resulting from the union of various rivulets which take their rise on the southern slope of the granitic hills of Hensbarrow. These unite their waters a short distance above the town of St. Austell, and two miles further down the valley receive, through a westerly depression, those collected on the high grounds in the vicinity of the ancient tin mine of Polgooth.

The fall of this valley, in the four miles which intervene between the bridge at St. Austell and the port of Pentewan is 115 feet, while its width varies from 100 to 200 yards.

The junction of granite with clay slate takes place a short distance above St. Austell, and consequently the bed-rock of the valley, throughout the last four miles of its course, consists entirely of slate.

According to Mr. J. W. Colenso, the Happy Union Streamwork, which may be taken as a typical example of deposits of this class, exhibited the following section :—[1]

1. River sand, silt, &c., 20 feet.
2. Sea sand, 20 feet.
3. Silt, 2 feet.
4. Sea sand, 4 inches.
5. Silt, 10 feet.
6. Leaves, nuts, acorns,[2] &c., graduating into 6 to 12 inches of silt, and 12 inches of decomposed vegetable matter.
7. Tin ground, 3 to 10 feet.
8. Bed-rock of clay slate.

These various deposits were made up of the following constituents:—

1.—A bed of rough river sand and gravel mixed with sea sand and silt. At the bottom of this, and extending into the bed immediately beneath it, was found a row of wooden piles six feet in length, sharpened at one end for the convenience of driving. These, which had apparently formed part of a foot-bridge, crossed the valley nearly at right angles; their tops being about level with the present low-water mark at spring tides.

2.—A stratum of sea sand, also about 20 feet in thickness, resting upon silt. Throughout this sand were scattered large timber trees, principally oak, strewn in all directions, together with bones of the Irish elk, *Megaceros hibernicus*, and of an ox, *Bos primigenius*, both belonging to extinct species. The bones of a large whale and two human crania were likewise discovered in this sand.

3.—Beneath the sea sand were 2 feet of silt enclosing a few stones, and, occasionally, bones with fragments of wood.

4.—A stratum of sea sand only, 4 inches in thickness, distinguishable from river sand by being finer and by containing fragments of marine shells.

5.—Beneath this was a layer of silt or "sludge" 10 feet in thickness, varying but little in texture, although its colour was in some places darker than in others. In this were numerous marine shells particularly those of *Cardium edule*, together with bones and horns of the deer and ox. The bivalve shells frequently occurred in regular layers, and when found were closed with their articulations downwards, thus justifying the opinion that the animals

[1] *Trans. Roy. Geol. Soc. Cornwall*, vol. iv. 1832, p. 29.

[2] Although Mr. Colenso does not mention acorns in his memoir, they were often found in this layer.

had lived and died where their shells were discovered. In this silt was a piece of wood evidently fashioned by human agency, which had probably floated in the sea, since the shell of a barnacle was attached to one end.

6.—A layer of leaves, hazel nuts, acorns, sticks and moss, varying from 6 to 12 inches in thickness. The moss, which was in a very perfect state of preservation, extended across the valley, and had the appearance of having grown where it was found, at a depth of about fifty feet below the present level of the sea at high water. Beneath this was a stratum of dark silt 12 inches thick, much mixed with decomposed vegetable matter.

7.—To this followed the tin ground, or stratum in which the whole of the tin ore was found. This lay on the solid rock, varied in thickness from 3 to 10 feet, and usually extended completely across the valley. The stony constituents of this stratum were rounded fragments of the granitic and schorlaceous rocks forming the hills north of St. Austell, but fragments of both "greenstone" and clay slate were occasionally met with.

By far the larger portion of the tin ore lay at the bottom of this stratum; but it was also sometimes found in the higher portions of the bed, where, for a thickness of a few inches, the ground was blackened by the presence of tin oxide. The fragments of ore varied in size from the finest sand to pebbles of ten pounds in weight, while boulders, richly impregnated with cassiterite and weighing above two hundred pounds, were not of unfrequent occurrence. A few grains and small nuggets of gold were picked up from among the tin ore, but the remains of no vertebrate animals were ever observed in this horizon. Stumps and roots of trees which had evidently grown and fallen upon the same spot were, however, not uncommon, while immediately on the top of the tin ground an oyster bed was discovered with the shells still firmly attached to the larger stones and to stumps of trees.

8.—The floor or bed-rock upon which these deposits rested is a blue "killas" or clay slate of the kind composing the adjoining hills and neighbouring sea-cliffs. In many places this rock showed indications of erosion, while in others no evidence of any kind of abrasion could be detected.

The bottom of the tin ground at Pentewan was about sixty feet below the present level of high water, and there can be no doubt that the stanniferous gravels were deposited prior to the growth of the woody stratum above them. Similar phenomena have been observed in the Par Valley, at Carnon, in the Fal estuary, and in various other localities. This indicates a general subsidence of the land, and the existence at a former period of a more extended coast-line. On the other hand, a connection has been traced by Mr. Carne between a forest bed covering tin ground in the Marazion Marsh, and the submerged forest in Mount's Bay; which further points to a general correlation between the forest beds over the tin ground, and the well-known submerged forests around the south-western coast of Cornwall.

At Huel Virgin, a mile higher up the valley than the Happy Union Streamwork, the overburden contained no sea sand, but was composed of silt and gravel only; the tin ground being found at a depth of thirty-two feet below the surface. Here, resting on the tin-ground, were found two pieces of oak artificially pierced with holes, as were also several oak stakes sharpened and driven into the ground. This streamwork was worked in the usual way by an open terraced cutting, while the water flowed through a culvert to suitable pumping machinery.

It is a remarkable fact, that whenever this excavation was allowed to remain open sufficiently long, certain plants invariably made their appearance along given horizons, to the almost total exclusion of all other species. In this way the first warm weather after the ground was opened, brought with it from a band of bluish silt about 10 feet from the surface, an abundant crop of foxglove, *Digitalis purpurea;* while in a band of clay about 15 feet above the tin ground, a dark rough-leaved willow, not common elsewhere in the district, grew most abundantly.

The cassiterite of Cornish streamworks is in the form of more or less rounded massive fragments, as water-worn crystals, and as wood-tin. With but few exceptions all the larger fragments bear evidence of attrition, and there can be no doubt that, as a whole, the tin ore has been brought together by the mechanical action of water.

There are, however, in the British Museum, as well as in the Museum of the Royal Geological Society of Cornwall, fragments of antlers containing tin oxide, which appears to be pseudomorphous after the organic tissues. Many of these fragments are stated to have been found in the streamworks of the Pentewan and Carnon valleys. Some of the specimens preserved in the British Museum appear to contain a large quantity of tin, as in many parts the original structure seems to be almost entirely reproduced as cassiterite.

A specimen from the Penzance Museum, analysed by Mr. J. H. Collins, gave the following results :—

Calcium phosphate	80·04
„ carbonate	2·24
„ fluoride	·50
Iron disulphide	1·66
Ferric oxide	·62
Stannic oxide	2·60
Silica	·22
Organic matter and loss	12·12
	100·00

A microscopical examination of this antler showed that the oxides of tin and iron, as well as the pyrites, had penetrated to the interior of the mass, and were visible throughout its structure, although they are somewhat more abundant on the outside than towards the middle.[1]

Although the streamworks of Cornwall have long been practically exhausted, large quantities of detrital tin ore are still annually obtained in various parts of Australia, and in Malacca, Banca, and Billiton, in the Indian Archipelago.

b. Deposits resulting from Chemical Action.—The most important surface deposits belonging to this class are those of bog and lake iron ores. These, which often contain oxide of manganese, although generally somewhat impure, are essentially hydrated peroxide of iron ($H_6Fe_2O_6$), containing when pure, 14·42 per cent. of water. Phosphoric acid is, however, frequently present in sufficient quantity to affect their value as a source of iron.

Although not at present much worked in Great Britain, these ores probably to some extent supplied the earlier forges established in the Weald of Kent and Sussex, which, during several centuries, furnished a very considerable proportion of the iron manufactured in England. The ore chiefly employed was, however, a clay ironstone obtained in the immediate neighbourhood. Bog and lake iron ores occur plentifully in various parts of Europe, particularly in North Germany, Sweden, Norway, and Finland, and are largely employed in the manufacture of iron. Bog iron ore is abundant in the United States and Canada, and in the latter country it is somewhat extensively employed. This

[1] *Mineralogical Magazine*, vol. iv. 1882, p. 115.

mineral is sometimes hard and compact; while at others it is friable and granular, occasionally enclosing the petrified forms of vegetable organisms. Concretionary nodules, as well as oolitic and pisolitic forms of this ore, are of frequent occurrence. In all cases it is the result of the alteration of other mineral substances containing iron when acted upon by air, moisture, or acids, and is, to a large extent, due to the oxidation of pyrites, and to the action of carbonic acid upon siderite, &c. The decomposition of various ferriferous minerals, such as mica, augite, and hornblende, also contributes largely to the formation of ores of this class.

Large quantities of lake iron ores are annually obtained in Norway and Sweden by dredging from the bottoms of the lakes so numerous in those countries. The ores may occur either on the spot in which they have been precipitated, or they may, on the contrary, be carried by the force of running water into lakes or ponds at some distance. They are, however, usually found in the neighbourhood of rush-banks, and on the slopes and shallows of some of the larger and deeper lakes, in patches varying greatly in extent and thickness. The work of collecting these ores is limited to the winter months, when, the lakes being frozen over, they are obtained by breaking holes in the ice and scooping them up by means of perforated shovels. Ores of this class are being continually reproduced, and lakes in which they had become completely exhausted by dredging, have, after the lapse of a quarter of a century, been again found to contain beds several inches in thickness, which must necessarily have been deposited during that period.

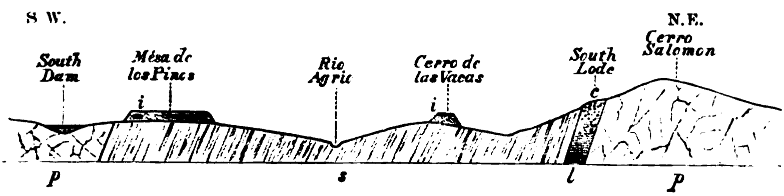
Attention was first called by Kindler to the importance of the effects produced by decaying vegetable matter on the solubility of ferric hydrates.[1] He observed that where pine trees had been planted upon sand-hills in such a position that falls of sand were occasioned by the action of running water, the ferruginous and quartzose sand was rendered colourless around decaying roots, and that it became in the course of a few months as white as if it had been treated by an acid. The action of a root one-sixth of an inch in diameter whitens the sand to a distance of from one to two inches around it.

A remarkable bed of compact and exceptionally pure iron ore of this class forms the capping of a hill at Rio Tinto in the province of Huelva, Spain, in close proximity to the celebrated

[1] *Poggendorff's Annalen der Physik und Chemie*, vol. xxxvii. 1836, p. 203.

copper mines of that name. In Southern Spain deposits of cupriferous iron pyrites, having a general direction somewhat north of west and south of east, extend from near Seville to within the Portuguese frontier. At Rio Tinto the deposits of this mineral are very extensive, and consist of a compact and intimate admixture of iron pyrites with a little copper pyrites, through which strings of the latter mineral sometimes ramify.

Although these mines have been worked, and the copper smelted, from time immemorial, it is evident from coins which have been discovered, that their great development under the Romans took place during the first four centuries of the Christian era. The prevailing rocks throughout the region are clay slates, which, from the evidence of various fossils, are apparently of Silurian, Devonian, and Carboniferous age. These slates are broken through by dykes of quartz-porphyry, which frequently form one of the walls of the deposits of cupriferous pyrites.



p Porphyry. *s* Slate. *i* Iron caps. *l* Lode. *c* Capping of lode.

FIG. 1.—Transverse Section; Rio Tinto.

Fossiliferous iron ore forms a cap three-fifths of a mile long, with an average width of 140 yards, on the top of the Mésa de los Pinos 984 yards south of the great open cutting at Rio Tinto. Its surface is approximately level, but its depth varies from one to seventeen yards in accordance with the conformation of the surface of the rock upon which it lies. The slate beneath it is bleached and to some extent decomposed.

The relative positions of the several formations will be understood on referring to Fig. 1.

On the extreme right is a broad hard porphyritic dyke forming the north wall of the south lode, next to which is the great vein of pyrites, which at this point has only one-third of its greatest width. Next in succession, to the south, comes a band of slate which is again penetrated, on the left, by a broad dyke of quartz-porphyry, now much decomposed. The upper part of the pyrites vein has, to a considerable depth, been converted into a ferruginous capping, of which a large portion has been removed by denudation. The stratum of iron ore forming the surface of the Mésa de los Pinos has precipitous sides; and a small outlying patch of a similar formation occurs, within a metre of the same elevation, at the Cerro de las Vacas. Numerous fissures occur in the surface of the larger deposit of iron ore, and, out of these, pine trees formerly grew, their presence giving the name to the locality.

An exceptionally pure specimen of this iron ore afforded on analysis the following results:—

Water	13·25
Silica	1·53
Ferric oxide	84·65
Alumina	trace
Phosphoric anhydride	·14
Sulphur	·23
	99·80

During the process of quarrying this ore, the presence was observed of the fossil remains of the leaves and seeds of plants belonging to species still growing in the neighbourhood, as well as of several well-preserved beetles.

Any doubt as regards the recent character of these fossils has been removed by Mr. W. Carruthers, who found the specimens from Rio Tinto to contain fragments of the following plants, which he was enabled to identify:—Leaves and acorns of *Quercus ilex*, Linn.; leaves and seeds of a two-leaved species of *Pinus*, most probably *Pinus pinea*, Linn.; the cone of *Equisetum arvense*, Linn.; and a small branch of a species of *Erica*. The greater portion of some specimens of the ore represented a thick growth of moss, but it was impossible to say of what species. The whole was permeated by minute branching roots, showing that the vegetation was formed as a peat-moss, the oak and pine leaves having been carried or blown into it. The plants evidently belong, all of them, to species still found growing in Spain. In addition to these fossils, this deposit occasionally contains minute concretionary patches of imperfectly crystallized quartz.

The origin of this deposit of iron ore can scarcely be doubtful. At the time of its formation a marsh or shallow lake extended from beyond the Mésa de los Pinos to the foot of Cerro Salomon, and into this flowed solutions of iron salts resulting from the decomposition of the upper portions of the immense mass of pyrites constituting the south lode. From these salts oxide of iron was deposited, as in the case of bog iron ores generally; and finally the valley of the Rio Agrio was eroded, as well as that south-west of the deposit, leaving the Mésa capped with iron ore, while a small patch of the same mineral was left at the Cerro de las Vacas.

That this deposit took place at a comparatively recent date is evident from the fossils it contains, and it is equally certain that the erosion of the valley is older than the occupation of the district by the Romans. Not only are remains of buildings and other works belonging to the Roman period found in the valley, but the Roman gravestones, of which many are still scattered over the district, are invariably made of this iron ore.

STRATIFIED DEPOSITS.

Ore beds are metalliferous aggregations interpolated between rocks of sedimentary origin belonging to every geological age. They lie parallel to the stratification of the enclosing rocks, and follow all their contortions. In this way ore beds form synclinals or *basins* and anticlinals or *saddles*, of which the upper portions are often removed by denudation.

When a bed has been tilted from a horizontal position its inclination towards the horizon is called its *dip*, and the amount of this dip may be stated either in degrees, or by saying that it falls a certain number of feet or inches in a given distance. The line at right-angles to the dip of a bed is called its *strike*, and is described as its line of compass bearing, either true or magnetic, though the former is to be preferred.

The dip may consequently be defined as the line of greatest inclination that can be drawn on the surface of a bed, while the strike is the line at right angles to its dip.

The line along which a bed cuts the surface of the ground is called the *outcrop* or *basset*, and this, where the surface is horizontal, will correspond with the strike. Under no other circumstances will this be the case unless the bed be absolutely vertical; for all other inclinations the outcrop will wind around with the irregularities of the surface, the deflections becoming greatest where the dip is least considerable.

The layer immediately beneath a metalliferous bed is called its *floor*, while that which lies directly above it is its *roof*. The thickness of a bed is measured by a line perpendicular to its floor and roof. The thickness often varies considerably in different parts, and the bed may gradually thin out and finally disappear. In many cases there are no very sharp limits between a metalliferous bed and the enclosing rocks.

Some beds consist of one or more layers of a compact ore, such as limonite, hæmatite, or siderite, distributed with considerable regularity throughout; the amount of ore depending on the thickness of the deposit. In other metalliferous beds, and especially in those consisting of sphærosiderite, the ironstone forms nodules enclosed in particular zones of a stratified rock. A true ore bed never possesses a combed structure made up of symmetrical layers such as is common in mineral veins, and is usually without the crystalline texture so frequently observed in veinstones.

Like all other rocks, metalliferous beds are frequently divided by fissures; these are sometimes mere rents; but there is often not only a severance of the strata, but also a displacement of the rocks severed. In this way portions of beds which were originally continuous are found at very different levels on the opposite sides of a fissure, and hundreds of feet may intervene between the disunited portions of a bed once upon the same plane. In such cases the fissure is by geologists called a *fault*, and is known among miners as a *slip*, *slide*, *heave*, *throw*, *trouble*, or *check*. The amount of disturbance produced by a fault, measured vertically, is called its *throw*, and is often spoken of as an *upthrow* or a *downthrow*, according to the side from which it is approached by the workings of the miner. When the surface is horizontal its amount may be measured perpendicularly from the outcrop, but when this is not the case it is measured from an assumed horizontal plane. If a bed, where it is cut by a fault at *a*, Fig. 2, be 50 yards from the surface A B or from an imaginary horizontal line, and the other portion of the bed on the opposite side of the fault be at *b* 100 yards below the same line, the throw of the fault is said to be 50 yards without regard to the distance measured horizontally either from A to B or from *a* to *b* along the fault. When the outcrop of a bed is cut by a fault, the distance between the two parts of the broken bed, measured at right angles to its strike, is usually spoken of as the *heave* of the fault. The character of a fault is much influenced by the hardness and rigidity of the rocks traversed by it, while its effect mainly depends on the peculiarities of the beds through which it passes, with regard to their amount of dip and degree of contortion; the result is also much influenced by the direction and inclination of the fault itself.

When beds of a soft and yielding nature are traversed by a fault, the fissure is often bounded by two mere planes of division, the surfaces of which are frequently polished and striated by the friction to which they have been subjected. These polished surfaces are known under the name of *slickensides*, and occur most numerously in the neighbourhood of mineral veins, and in rocks which have been much subjected to disturbing influences. In some cases, although the planes bounding the fracture along the line of fault may be apparently sharp and clean, the beds on either side are traversed by numerous subordinate

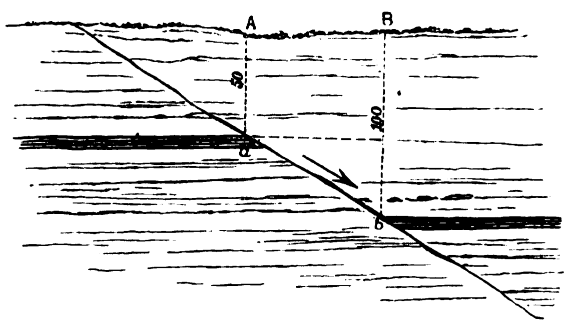


FIG. 2.—Section of a fault.

slickensides, as though a tremulous grinding motion had been communicated to the beds for some distance.

In many cases beds end abruptly at a fault without any kind of disturbance in their direction, as seen in Fig. 3, where the throw is measured by the vertical distance between the two portions of the beds *a*, *b*, *c*, or *d*, respectively. They sometimes, however, appear to have been, to some extent, distorted and bent out of their original position along the plane of fault. This bending of the beds usually occurs in the way indicated in Fig. 4, as might be anticipated from the supposed nature of the motion which has taken place, and they are then said to *dip to the downthrow* and *rise to the upthrow*. J. Beete Jukes states that he had frequently been told by coal miners that the reverse of this bending sometimes takes place, and that he had himself seen an example of this reversed flexure at the Himley Colliery, near Dudley, but was unable to explain its cause.[1]

A series of parallel faults situated at short distances from one another sometimes traverse a district for considerable distances, and if the throws are all in the same direction, they break up the strata into a number of steps as shown in Fig. 5.

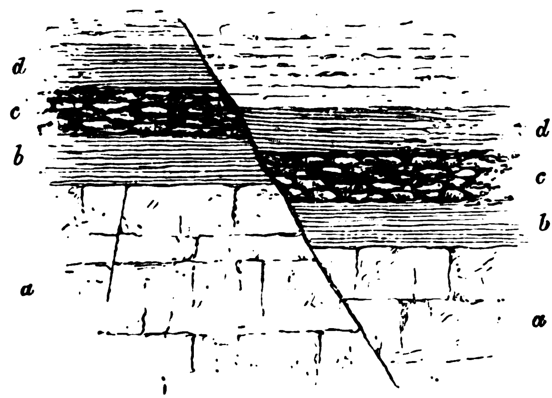


FIG. 3.—Beds faulted without distortion; section

When any of the throws are in contrary directions, it is manifest that an irregular disruption of the beds must be the result. It has been suggested that in speaking of the inclination of faults, it might perhaps be better not to employ the term dip, as

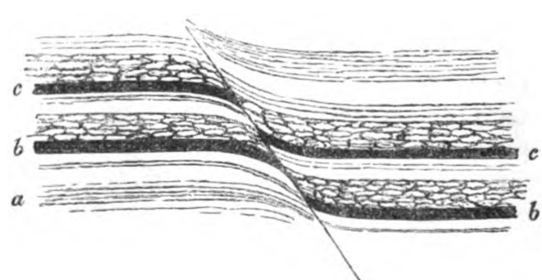


FIG. 4.—Beds distorted by a fault; section.

in the case of beds, but to adopt that of *hade* or *underlie*, were it not for the fact that miners generally use the terms hade and underlie in the sense of an inclination from the vertical. The underlie is the complement of the dip, which means the inclination

[1] "The Student's Manual of Geology," 3rd Edition, 1872, p. 201.

from the horizon, and thus a plane which dips 60° will underlie 30° from the vertical. When, therefore, these terms are used, it is necessary that it should be understood in what sense they are employed. The word dip is always intended to express an inclination measured from the horizontal, while hade and underlie are employed to signify an inclination from the vertical.

Faults are sometimes perpendicular, and their throw is then not attended by any horizontal displacement; they are, however, much more frequently inclined, and their dip is almost universally in the direction of the downthrow. When such is the case it follows that whatever may be the inclination of a fault, no part of any bed can be brought vertically beneath any other portion of the same bed, nor can any superior strata be brought immediately under those originally above them. Exceptions to these rules occur in rare instances only, and are known by the name of

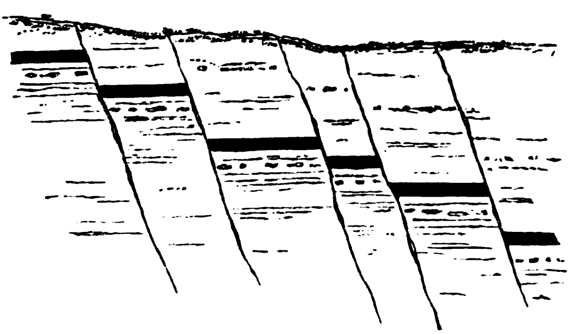


FIG. 5.—Step faults.

reversed faults. A diagrammatic representation of such a fault is given in Fig. 6, where it will be observed that the beds on the right of the fissure must either have been forced upwards, or have remained stationary, while those on the other side were carried downwards along the line of fissure. Although the occurrence of reversed faults is decidedly exceptional, they are, nevertheless, occasionally met with.

It is manifest that when strata which have been much contorted are traversed by faults differing from one another both in dip and in direction, the changes resulting in the relative positions of the beds will sometimes be of a very perplexing character. A consideration of complicated examples of faulting would occupy more space than can be here devoted to the subject, but a careful study of such phenomena on the ground, having due regard to the foregoing general rules, will enable the observer to unravel all ordinary complications which may present themselves.

a. DEPOSITS CONSTITUTING THE BULK OF METALLIFEROUS BEDS FORMED BY PRECIPITATION FROM AQUEOUS SOLUTIONS.—Of all metalliferous ores those of iron and manganese occur most frequently in the form of beds, but although they are found in formations of all ages, their maximum development is in the older rocks. The Carboniferous rocks of both England and America are especially rich in interstratified beds of argillaceous ironstone. Argillaceous carbonate of iron is one of the most important sources of iron in the United Kingdom, and furnishes a large proportion of the iron annually produced. The most important deposits of red hæmatite in this country are enclosed

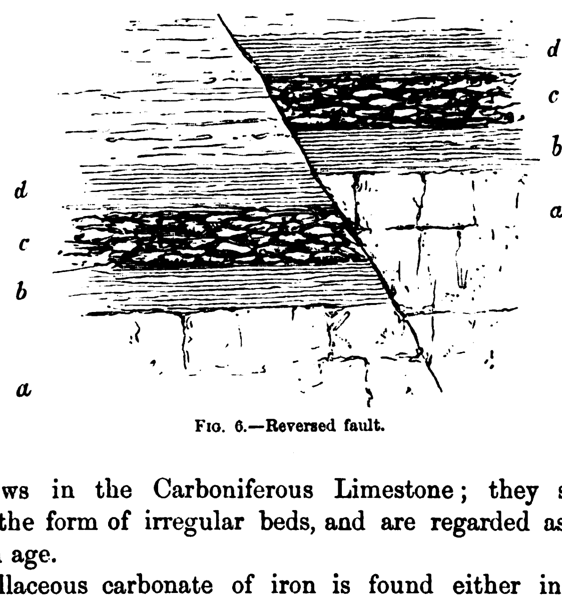


FIG. 6.—Reversed fault.

in hollows in the Carboniferous Limestone; they sometimes assume the form of irregular beds, and are regarded as being of Permian age.

Argillaceous carbonate of iron is found either interspersed through the clays and shales of the Coal-measures, or, less frequently, among the argillaceous members of Secondary or Tertiary strata. The nodular variety, which is the most abundant, essentially consists of carbonate of iron associated with carbonates of lime, magnesia, and manganese; it also invariably contains a considerable proportion of clay. In some instances the nodules of ironstone coalesce into beds, but these are usually restricted both in extent and in thickness. Nodular ironstone is for the most part concretionary in structure, being formed of concentric deposits, which frequently enclose fossil fish, shells, or plants. Ferruginous septaria are often traversed by fissures similar to those produced by the shrinking of clay in drying, and these are filled, as in veins, with such minerals as calcite and quartz with, occasionally, pyrites, blende, galena, millerite, or hatchettine, the two last being associated together in the clay ironstone of Dowlais in Glamorganshire.

Sphærosiderite, when freshly broken, ordinarily presents a yellowish or bluish-grey fracture, which, owing to a superficial peroxidation of some of the iron, becomes brown on exposure. Clay ironstones contain from about 29 to 37 per cent. of iron, and phosphoric acid is usually present in varying amounts.

Blackband is a clay ironstone containing a considerable amount of carbonaceous matter, and is exceedingly valuable from the cheapness with which it can be calcined without the addition of fuel. The calcined residue from this ore contains from 50 to nearly 70 per cent. of iron. In the coal-fields of Western Scotland several blackband measures are known, having an aggregate thickness of nearly six feet. In Staffordshire it occurs in beds of from four to nine feet in thickness, and it is also found in numerous small irregular beds in North Wales. The Rhenish and Westphalian coal-fields likewise yield this ore.

The most productive iron-bearing members of the Secondary rocks are the Middle Lias, Great Oolite, Wealden, and Lower Greensand, yielding brown hæmatite and earthy carbonate which, although in the majority of cases of low quality, are rendered of great commercial importance by the extremely cheap rate at which they can be mined. In France and Southern Germany large quantities of *bean ore*, a coarse-grained pisolitic iron ore, is procured from irregular deposits in rocks of Oolitic age. The amount of iron in ores of Secondary age usually varies from about 32 to 48 per cent. while the proportion of phosphoric acid is sometimes as high as two per cent.

There is but little iron ore of Tertiary age in this country, the principal deposit being at Hengistbury Head in Dorsetshire. Tertiary iron ores, however, occur on the Continent, and are somewhat extensively collected from surface deposits in France, Germany, and elsewhere; many of these deposits are of a detrital character.

The separation of mineral matter from masses of rock through which it was originally but sparsely disseminated is well exemplified in the ironstone nodules of the Coal-measures, which evidently result from the separation and aggregation of carbonate of iron from the surrounding shales and clays.

The calcareous nodules of the Lias and the argillaceous deposits known as septaria, and similar nodules in the Old Red Sandstone of Scotland and South Wales, sometimes termed "cornstones," have, in the same way, resulted from the separation of a small amount of calcareous matter, originally distributed through the mass of argillaceous and siliceous sediments. Not unfrequently these argillo-calcareous nodules contain fragments of the enclosing stratified rock, layers of which may be traced through them; the laminæ having the same direction as the mass of the rock of which they originally formed part. This has been observed in nodules from the Lias of Lyme Regis, and in the calcareous septaria, containing fossil fish, in the Old Red Sandstone of Cromarty, &c. In the same way siliceous particles originally disseminated in calcareous rocks such as Chalk, Portland Limestone, Coral Rag, and Carboniferous Limestone, have separated out and become segregated into the various forms of flint, chert, or hornstone now occurring in those rocks, and sometimes enclosing portions of the original beds, or a nucleus of some fossilized organism. Occasionally the siliceous matter has filled the more or less vertical fissures of calcareous rock, or even replaced its original substance;[1] such veins of flint are well seen in the chalk cliffs of Ramsgate, and in the Portland beds of Tisbury, Wiltshire. In a similar manner the nodules of phosphate of lime which occur in certain fossiliferous strata have evidently been derived from the aggregation of their components, previously distributed in the mass of the original deposits. It is well known that the plastic clay prepared for the manufacture of pottery and porcelain is mixed with finely ground silica, and from such mixtures, if not used in proper time, it is stated the silica becomes aggregated into hard lumps or nodules, which render them useless for the purpose of porcelain making.

b. BEDS ORIGINALLY DEPOSITED FROM SOLUTION, BUT SUBSEQUENTLY ALTERED BY METAMORPHISM.—Iron ores occurring in highly metamorphosed rocks are usually either in the state of ferric oxide, $Fe_2 O_3$, or magnetite, $Fe_3 O_4$. Both these minerals are obtained from beds, lodes, and massive deposits, for the most part enclosed in rocks of Cambrian, Silurian, Devonian, or Carboniferous age. Red hæmatite is sometimes crystalline, sometimes fibrous, columnar, botryoidal, granular, or compact. Among the most important European deposits of hæmatite are those of the Island of Elba, of Dalkarlsberg near Nora, and those of the Island

[1] T. Rupert Jones, "Reliquiæ Aquitanicæ," 1875, p. 202.

of Utö, in Sweden; in the two latter localities it is associated with magnetite. In the Island of Utö the ore is made up of parallel layers of a very brilliant specular variety of hæmatite with quartz, and is therefore not unlike the rock known in Brazil as *itabirite*.

In the Huronian rocks near Marquette, on the southern shore of Lake Superior, are large deposits of schistose hæmatite, known by the name of *iron slate* or *specular schist*, which have long been extensively worked. The strata enclosing these ores are much contorted, and are chiefly composed of talcose and chloritic schists, gradually passing into parallel bands of jasper and hæmatite. Much of the rock, although highly ferriferous, is still too siliceous to be worked for iron; but beds of solid hæmatite, of great thickness and free from earthy impurities, are quarried at the Republic and Superior Mines in the district. In addition to hæmatite affecting the usual crystalline form, these beds enclose numerous crystals of the octahedral variety of ferric oxide known as *martite*. The celebrated Pilot Knob Mine near St. Louis, Missouri, is worked on ores of a nearly similar character to those of Lake Superior. There are no important continuous beds of hæmatite in the United Kingdom.

Magnetic iron ores, when they occur in a massive form, usually contain a larger proportion of oxygen than is indicated by the formula $Fe_3 O_4$, thus indicating the presence of a certain amount of hæmatite. Magnetite occurs in extensive irregular beds or stratified deposits in various European countries, being usually enclosed in crystalline metamorphic rocks and associated with such minerals as hornblende, epidote, garnet, idocrase, chlorite, apatite, quartz, felspar, pyrites, &c. It is extensively worked at Dannemora, Norberg, Philippstadt, and Taberg in Sweden, in the neighbourhood of Arendal in Norway, in Russia, and in Lapland. The largest known European deposit of iron ore of this class is probably that of Gellivara, in Swedish Lapland, situated about ninety miles from the head of the Gulf of Bothnia. It here forms a hill of considerable height made up of parallel interlaminations of magnetic and specular iron ores associated with quartzose and hornblendic rocks. One of the beds is nearly 200 feet in thickness and extends over a large area; about 80 feet of this bed is however, contaminated by the presence of apatite, leaving a thickness of nearly 120 feet suitable for iron-making.

An extensive deposit of magnetic iron ore, which has been worked from time immemorial, occurs at Traversella in Piedmont, where it forms a large crystalline mass in talcose schists and dolomites. Magnetite is found under nearly similar circumstances at Berggieshübel in Saxony, where it is extensively wrought. At Nijni Tagilske and Kuschvinsk, in the Ural, it is mined in a doleritic porphyry. In this country magnetite does not occur in the form of beds, but it is met with in small quantities at Brent in South Devon, as well as near Penryn in Cornwall; in the latter place it forms a vein, three feet in width, which contains a small quantity of oxide of tin.

There can be but little doubt that the majority of these stratified deposits of crystalline iron ores were originally thrown down in a hydrated form from aqueous solutions; but having been subsequently exposed to metamorphic influences, they have not only lost their combined water, but, like the rocks enclosing them, have become crystalline. It is probable that in some instances, they may have been deposited as carbonate of iron, which first lost its carbonic acid and subsequently became more highly oxidized.

Professor J. S. Newberry, in a valuable contribution to the *School of Mines Quarterly* for November, 1880, enumerates the sources whence the necessary supply of iron may be derived.

In the oldest existing rocks of which we have any knowledge iron is an important constituent of many minerals, such as hornblende, garnet, biotite, &c., and in rocks of this description deposits of iron ore, commonly as magnetite in the granites and as hæmatite in the slates, are of frequent occurrence. Deposits of this class were formerly supposed to be of eruptive origin, but more recently it has been pointed out by various authors that, almost without a doubt, they are of sedimentary origin. The magnetites and hæmatites of the older rocks become by exposure converted into hydrated ferric oxide, which alteration is constantly attended by a change of structure resulting in exfoliation. Iron oxide thus becomes mixed with the soil, where it is exposed to the action of carbonic acid and various other acids, resulting from the decomposition of vegetable matter. By these it is dissolved, and becomes a constituent of the surface drainage of the country, to be carried a greater or less distance, and finally deposited in the form of an ore of iron. In the same way various minerals containing iron, such as hornblende and garnet, forming constituents of the rocks, are gradually dissolved by carbonic acid and other solvents, and thus pass into solution. Iron pyrites undergoes a somewhat different form of decomposition, since both its constituents become oxidized with the formation of sulphate of iron, from which oxide of iron is ultimately deposited.

In continuation of this subject Dr. Newberry then proceeds to say:—"Having now got the insoluble peroxide of iron into a soluble form, let us follow it in its travels. All the drainage of a forest-covered country may be asserted to contain iron. Where the rocks and soils hold this metal in unusual quantities the amount dissolved and transported is proportionately great, and many of the springs are chalybeate. Wherever these solutions of the salts of iron are exposed to the air they absorb oxygen, and the iron is converted into the hydrated sesquioxide. This we see in the precipitate of iron springs as yellow ochre; in bogs and pools it forms an iridescent film, which, when broken, sinks to the bottom of the water. If it there finds decaying organic matter, it is robbed of a portion of its oxygen, which unites with the carbon to form carbonic acid, and this, bubbling to the surface, escapes. The iron thus becoming again a soluble proto-salt, and floating off, absorbs more oxygen, and carries this also to the organic matter, continuing to do this until all is oxidized; then it is precipitated as limonite or bog iron ore. Thus it will be seen that, under such circumstances, iron plays the same part that it does in the circulation of the blood, where it is oxidized in the lungs and carbonized in the capillaries, serving simply as a carrier of oxygen." Beds of iron ore thus formed naturally become metamorphosed at the same time as the enclosing rocks, and give rise to deposits either of magnetite or hæmatite in accordance with varying conditions.

c. ORES DISSEMINATED THROUGH SEDIMENTARY BEDS, IN WHICH THEY HAVE BEEN CHEMICALLY DEPOSITED.—The most typical example of a bed of this class is exhibited in the *Kupferschiefer*, or copper-bearing shale of Mansfeld, in Prussian Saxony, where mining has been for many centuries extensively carried on. The metalliferous bed occurs in the *Zechstein*, a member of the Permian formation wanting in this country, but regarded as being equivalent to the Magnesian Limestone of England. At Mansfeld the highest stratum of the series consists largely of unstratified gypsum, in which are numerous cavities, locally called *Gypsschlotten*, caused by the solvent action of water upon sulphate of lime. With the gypsum is associated a soft bituminous dolomitic limestone, locally known as *Asche*, and beneath this follows a stratified fetid limestone, below which is the true Zechstein, giving name to the formation. In depth this passes into a bituminous marly shale, the lowest portion of which, seldom above eighteen inches in thickness, constitutes the chief copper-bearing stratum, extending with wonderful regularity for many miles. Of this sometimes only from four to five inches is sufficiently rich to pay the cost of smelting; the proportion of copper in the ores treated varying from two to five per cent. The ore is for the most part an argentiferous fahlerz; but, in addition to this mineral, copper pyrites, copper glance, erubescite, native copper, melaconite, cuprite, galena, blende, copper-nickel, and iron pyrites are present. Native silver is but rarely met with, as are also antimony, bismuth, and arsenic.

Under the copper shale is a calcareous sandstone, varying in colour from white to grey, which is in part a conglomerate. This, in accordance with its colour, is called either the white layer, *Weissliegendes*, or grey layer, *Grauliegendes*, and sometimes contains copper ores. The regular bedding of these strata is frequently disturbed by faults, which, although they themselves rarely contain ore, appear to have exercised considerable influence on the metalliferous contents of the strata traversed by them. This is indicated by a marked increase or decrease in the amount of ore contained in the beds for considerable distances; the effect sometimes extending as far as their intersection by the next fault.

At Frankenberg, in Hesse, where, among numerous other German localities, copper occurs in small quantities in the Zechstein group, the true ore-bearing bed consists of a light crumbling clay, and the ore is not, as at Mansfeld, disseminated in microscopic particles, but assumes the form of fossil plants. The stalks, fruit and leaves of these, are, in some cases, converted into either tetrahedrite, or copper glance, while in others the plants have become converted into coal, and are traversed by numerous strings of copper ore. Iron pyrites is rarely associated with the ores of copper in the Frankenberg deposits.

The remarkable beds of crystalline sandstone which are worked for lead ore at Commern, in Rhenish Prussia, are of Lower Triassic age, and may be regarded as belonging to the class of deposits at present under consideration. They are situated at the extreme northern end of the Eifel, the ore-bearing rock being a white sandstone of great thickness, which is covered by red sandstones and conglomerates. The upper portions of the metalliferous rock, which alone are sufficiently rich to repay the expenses of working, are thickly charged with concretions, varying in size from a pin's head to a pea, which are made up of quartzose sand cemented by galena. The roof of the bed, which consists of conglomerate, is not worked for lead, although it sometimes contains pebbles partially coated with galena. In the upper beds large spheroidal concretions of brown ironstone are abundant, some of them being perfectly consolidated, while others are still in a soft state. These nodules contain small quantities of chromium, vanadium and titanium, the last-named metal being present in largest amount.

The workings are carried on partly by open-cast, and partly by underground mining. When the over-burden does not exceed 100 feet in thickness the metalliferous bed is stripped, the overlying rock being removed by a series of terraces. When, however, in following the deposit to the dip, the covering becomes of a greater thickness than that indicated, levels are driven into the bed, and the ore is won by a system of irregular pillar-working, not unlike that employed for winning the thick coal of South Staffordshire. The rock, although soft, usually stands without timber, but when once broken from the mass it crumbles so readily that the nodules of impure lead ore are separated from the unproductive sand by the use of drum-sieves. This sifting is carried on in the mine itself by manual labour, the nodules of lead ore alone being sent to surface, while the sand separated from them is employed for filling the exhausted workings. The nodular galena mixed with sand is subsequently stamped and dressed in the usual way, but the carbonate of lead, a considerable amount of which is present in the rough ore, is to a large extent lost in the operation. The annual production of lead from this district is very considerable, and the lead produced from the ores contains from $2\frac{1}{4}$ oz. to $4\frac{1}{2}$ oz. of silver per ton. Lead ores occur under somewhat similar circumstances near Gerolstein in the High Eifel, and in many other German localities, as well as in Nottinghamshire and Leicestershire in this country.

In the copper bearing Lower Keuper sandstones of Alderley Edge, Cheshire, carbonate of lead and some other oxidized ores of that metal, such as vanadinite and pyromorphite, are found, and here, as at Commern, they are sandstones to a large extent made up of crystalline grains of quartz.[1]

The presence at Commern of nodules of clay ironstone in some of the upper beds, together with the fact that the grains of sandstone of the lead-bearing horizon are frequently covered by a crystalline deposit of quartz, which has converted them into more or less perfect crystals, indicates extensive chemical action, in which water has performed an important part. Such deposits

[1] For description of various crystalline sandstones see paper by the author, *Quart. Jour. Geol. Soc.*, vol. xxxvii. 1881 p. 6.

can, therefore, only be regarded as segregations collected and transported by aqueous agencies, either from the rock itself, or from rocks in its more or less immediate neighbourhood.

Unstratified Deposits.

With the exception of certain ores of iron and manganese a large proportion of the metalliferous minerals is obtained from deposits belonging to this class. Fournet has remarked with regard to mineral veins, that metals having become of the first necessity to man he would naturally attach great importance to metalliferous minerals; and that it is to the study of their various modes of occurrence, and of their relations to phenomena affecting the adjacent country, that the science of geology owes its birth. Mineral veins are exceedingly variable in character, and sometimes exhibit appearances of a very perplexing and complicated nature. Unstratified metalliferous deposits are generally described as being either regular or irregular, but there is such a gradual passage from one of these forms to the other, that it is not always easy to determine to which category a deposit exactly belongs, and the advantage of such a classification is therefore, perhaps, somewhat doubtful. The *regular* unstratified metalliferous deposits comprehend *true veins, segregated veins* and *gash veins;* while the others, namely, *impregnations, stockworks, fahlbands, contact* and *chamber deposits,* are spoken of as *irregular.*

Veins are aggregations of mineral matter, differing in character from the enclosing rocks, in fissures formed in those rocks subsequently to their consolidation. All veins are not metalliferous, but even when they do not contain an ore of one or more of the useful metals they are often called *lodes.* Since veins have been deposited in fissures in rocks, they must necessarily be more or less completely tabular in form; but they not only divide or thin out towards their ends, but also exhibit through their whole extent considerable irregularities, resulting from unequal breadth as well as from deviations from their usual strike and dip.

The rock in which a vein is enclosed is called the *country* or *country rock.* Those portions of the country in contact with the vein are known as its *walls* or *cheeks,* and when the vein is not vertical that which is above it is its *hanging wall,* while that below it is its *foot wall.* The horizontal direction of a vein is called its *strike* or *course,* while its inclination with the horizon is its *dip*. In some of the mining districts of England the inclination of a vein is measured by its *underlie*, or angle of variation from the perpendicular.

A layer or sheet of argillaceous material often extends along the walls of a lode, between the vein itself and the enclosing country rock. This, which mainly consist of an unctuous clay, is called its *selvage* or *flucan*, and is sometimes slickensided or scored with curved, crooked, and unconformable striæ.

Bands of compact siliceous rock often occur in the immediate vicinity of the fissures enclosing mineral veins, and more frequently accompany tin ores than ores of copper. This hard quartzose material occasionally contains a sufficient amount of tin to repay the expenses of working, and when this is the case it is generally regarded as forming part of the lode. When, on the contrary, it contains no tin ore, or not a sufficient amount to pay, it is called *capel* by Cornish miners, and is regarded as a portion of the country rock. It is therefore often difficult to define the difference between an ordinary tin veinstone and a tin capel. Microscopical examination of thin sections of capels shows that they are often mainly composed of a quartzose base, throughout which crystals of tourmaline are thickly disseminated. Sometimes, and particularly when they occur in clay slates, capels consist principally of a mixture of quartz and chlorite. In other cases, both tourmaline and chlorite are present in the same capel, together with innumerable microscopic fragments of almost unaltered country rock. There can be but little doubt that in the majority of cases the "capels" of the miner are the result of extreme metmorphism of the country, produced by the agency of solutions from which the materials forming the lode itself were deposited. The replacement of crystalline and other rocks by quartzose pseudomorphs has been observed in connection with metalliferous veins in various parts of the world.

A *cross-course or cross-vein* is a vein intersecting another of greater geological age, which it frequently displaces from its original course. Cross-courses are sometimes, but not always, metalliferous; while, in many cases, they are composed either of quartz or of flucan. Cross-courses are often fissures filled with matter introduced by purely mechanical means, such as fragments of the wall-rock from above, or débris produced by the friction of their sides one against another. This sliding motion of one side of a fault over the other causes a violent trituration of the walls, and gives rise to friction surfaces which exhibit smooth and sometimes even polished faces, on which there are frequently parallel scratches or furrows indicating the direction in which the motion has taken place. The rubbing together of the surfaces of such dislocations produces a fine powder, which, with water, ultimately becomes transformed into a soft clay or flucan; the origin of selvages as well as of many cross-courses may be often thus explained. The horizontal dislocation of a lode is called a *heave*, while a vertical displacement is known as a *slide* or *leap*. The *outcrop* of a vein is that portion of it which appears at the surface.

Veins are exceedingly variable in thickness, some having a width of many fathoms, while others are represented by the filling of the most minute crack. The longitudinal extent of veins, like their thickness, is very variable; but as a rule, the widest are the most persistent both in length and in depth. Some metalliferous veins have been traced for a distance of several miles.

a. TRUE VEINS.—A true vein or lode may be defined as a fissure of indefinite length and depth, filled with mineral substances, and often containing metalliferous ores, traversing the enclosing rocks independently of their structure, and which is not parallel to their foliation or stratification. Veins of this class are generally admitted to have originated in fissures or dislocations caused by extensive movements of the earth's crust, and are therefore believed to extend indefinitely in depth. The two walls of a vein do not always coincide; so that the vein fissure is frequently at the same time a fault.

Fig. 7 is an ideal transverse section of a true or fissure vein pursuing its course across the planes of bedding, although cutting through them at a very acute angle. A true vein may at some part of its course coincide with the dip of the strata, or it may even send out spurs or branches following the lines of dip or cleavage, as shown in the figure.

The walls of metalliferous veins are seldom parallel to one another for any considerable distance, and their width consequently varies in different parts. This will be understood when it is remembered that the original fissure, which often passes through rocks of different degrees of hardness, never follows an absolute plane, and consequently that any movement of one of its sides must necessarily result in an opening of unequal widths. This will be clearly seen on referring to the annexed illustrations, in which Fig. 8, represents a line of fracture, *a b*, traversing the country rock, horizontally. In Fig. 9, *a b* is the same fissure, and if we were now to divide the paper by cutting it into two parts along this line, and to slide the lower portion from *a* to *a′*, its upper and lower edges would meet at the points *o*, leaving an irregular opening at *c* and lenticular spaces at *d*. If instead of sliding the lower portion of the divided paper to the right hand, we move it towards the left, as in Fig. 10, for about the same distance it

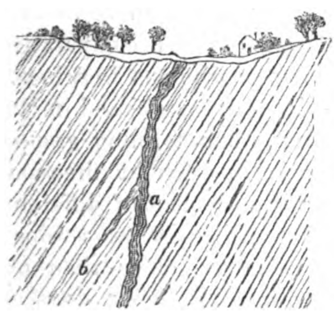


FIG. 7.—True vein, *a*, sending out a branch, *b*, corresponding with bedding.

was previously moved to the right, we obtain two lenticular spaces *c*, and an irregular opening *d*. The foregoing examples serve to show to what slight circumstances considerable variations in the character of an opening between the uneven surfaces of a fissure may be due, and explain one of the most frequent causes of the inequality observed in the width of mineral veins.

FIG. 8.

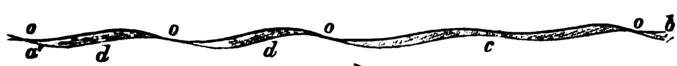


FIG. 9.

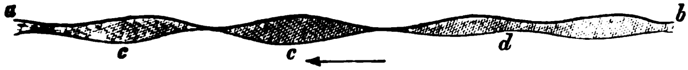


FIG. 10.

Opening of fissures; after De la Beche.

The elevation or depression of one of the sides of a more or less undulating fissure will necessarily give rise to similar results, and by this means irregularities in width will be produced similar to those caused by horizontal movements of the country rock. In order better to understand this, we may regard the foregoing diagrams as representing a fissure in transverse instead of in horizontal section.

Modes of Occurrence.—Among all the various forms in which metalliferous deposits are known to occur, true veins may be regarded as among the most important, since they are not only the usual source of many of the more valuable metals, but they also, from their persistency and comparative regularity, afford scope for systematic and continuous workings.

As a general rule, lodes are associated in clusters approximately parallel to one another, thus forming groups, which sometimes traverse the same district in different directions. An examination of the intersection or displacement of different veins at the points where they are divided either by cross-veins or by one another, shows that some of them are older than others; and thus, by observing which of them, respectively, cross others, or are crossed by others, their relative ages may be determined. In this way Mr. Carne was enabled, many years ago, to divide the veins of Cornwall into eight distinct groups according to their relative ages. The most manifest division, however, of Cornish veins is into those running east and west, usually yielding tin and copper ores, and lodes of which the direction is nearly north and south, commonly producing ores of lead.

Metalliferous veins are of more frequent occurrence in the older rocks than in the more recent, and the ores of certain metals are to a large extent confined to particular groups of rock. Lodes are most frequently found in districts where sedimentary beds have been penetrated by porphyries and other igneous rocks, and they are consequently more abundant in mountainous countries than in plains. Igneous rocks thus penetrating sedimentary beds are, as well as the beds themselves, frequently traversed by ore-bearing veins. Lodes are also often more productive in the vicinity of the junction of dissimilar rocks than elsewhere. This is particularly observed in Cornwall, where veins of tinstone and copper ore occur both in granite and *killas* or clay slate, but they are seldom found to be productive at any considerable distance from the junction of the two rocks.

The dip of metalliferous veins usually approaches more nearly to the vertical than to the horizontal. In the north of England their inclination from the vertical rarely amounts to more than 10°, while although averaging more than this in the mining districts of Cornwall, their mean inclination may be taken at about 20° from the vertical or 70° from the horizontal. The same lodes, within short distances, often vary considerably in direction, width, and dip, and they frequently split or divide into *branches* both in length and in depth; these branches may or may not again unite. If as in Fig. 11, a lode *a*, encloses a mass of the country rock, the included fragment *b* is called a *horse* or *rider*.

The dip of a lode is not always continuously in the same direction throughout its downward course, but, on the contrary, it sometimes becomes gradually vertical, and finally turns over, assuming an inclination in a direction exactly contrary to that with which it originally started from the surface. Numerous examples of veins varying greatly in their dip, were afforded by the Fowey

FIG. 11.—Horse, or rider.

Consols Mines, Cornwall, where some of the lodes divided, in depth, into two parts, apparently without again coming together, while few of the intersections, or junctions of one lode with another, were attended by any displacement of either of them.

Intersections and Faults.—It sometimes happens that veins meet one another without intersection or displacement; in such cases it is often assumed that the fissures are of the same age, and that they were contemporaneously filled with veinstone and ore. When veins meet at a very acute angle, they occasionally run parallel to one another for a considerable distance and subsequently diverge, as seen in Fig. 12. In other instances, after running parallel to one another for a greater or less distance, they ultimately cross, the newer vein passing through the older one as shown in Fig. 13. When a vein is intersected by a fissure, or by another vein of more recent age than itself, a fault or displacement is often the result, in which case the plane of the older vein on one side of the line of fault no longer coincides with its extension on the other side as shown in Fig. 14, in which *a* represents the dislocated vein and *c* the fissure or vein by which it has been intersected.

FIG. 12.—Diverging veins.

It frequently happens that a vein fissure is itself a fault, and in such cases the difference of level which occurs between similar strata on its opposite sides, is often called the throw of the vein.

All faults have been produced by a sliding of the country rock on one, or on both, sides of the fissure along which the movement has taken place. This may often be explained by a slipping down of its hanging wall upon its foot wall in the direction of its dip; sometimes, however, the country on the hanging wall side may

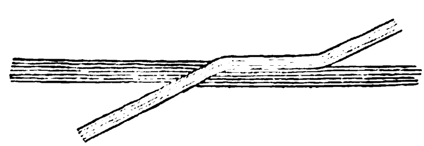


FIG. 13.—Veins crossing without displacement.

either have been forced upwards, or the two walls may have experienced unequal or contrary movements. In other cases the walls may have also experienced horizontal displacement.

The extent of the horizontal displacement of a lode by the sinking or rising of the country on one side of a fault, depends not only on the amount of dislocation it has experienced, but also on the angle which the direction of motion makes with the plane of the vein intersected. When this angle equals zero the effects, horizontally, of the fault will be imperceptible, and can only be recognized by similar portions of the intersected vein being found at different altitudes.

Complicated cases of faulting can only be understood after the position of the planes of the dislocated lodes has been exactly determined, and it has also been ascertained along which of the various fissures displacement has taken place, as well as the direction of the several movements.[1]

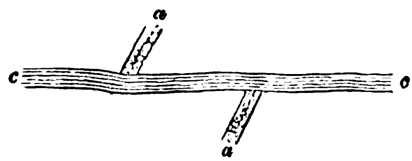


FIG. 14.—Vein displaced by a cross-course.

The parallel lodes *a b*, Fig. 15, seen in horizontal section are apparently heaved in contrary directions by the more recent vein *c*. This will be understood when it is remembered that the two lodes dip towards one another, and that any elevation of the country on the upper side A, of the cross-vein *c*, or any depression of the rocks on the lower side B, would produce the effect observed. It is further obvious that, in the case of lodes dipping in contrary

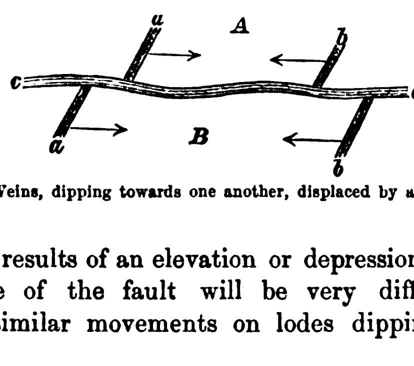


FIG. 15.—Veins, dipping towards one another, displaced by a cross-course.

directions, the results of an elevation or depression of the country on either side of the fault will be very different to those produced by similar movements on lodes dipping towards one another.

When a country is traversed by fissures, crossing and dipping in different directions, great care is often required in order to understand the relative positions of the several parts after

[1] Those specially interested in this subject should consult S C. L. Schmidt, "Theorie der Verschiebungen älterer Gänge," Frankfurt, 1810. C. Zimmerman, "Die Wiederausrichtung verworfener Gänge, Lager, und Flötze," Darmstadt, 1828. R. v. Carnall, *Karsten's Archiv.* vol. ix. 1832, p. 3. C. Combes, "Traité de l'Exploitation des Mines," Paris, 1844.

having been disturbed by faults, and when the surface has been subsequently ground down by erosion to an approximately common level. As an illustration let us suppose Fig. 16, after De la Beche, to represent such a case, *a b* being the present level of the country, and b^1, b^2, b^3 b^4, and b^5 representing so many different veins. Let this country be dislocated along the plane of the section so that *a′ b′* on the side B is lifted vertically above *a b* on the

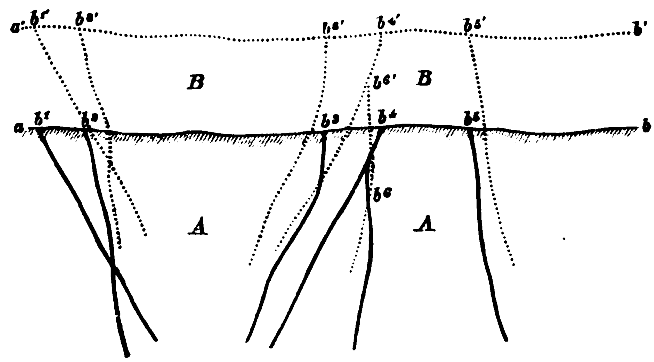


FIG. 16.—Effects of a fault on veins with different dips; section.

side A, or, what amounts to the same thing, the side A has sunk the same distance below the level of *a′ b′*. It will be seen that although the amount of vertical elevation has been common to all of the lodes, they now occupy on the surface *a b*, very different positions and distances from one another than they did originally, according to the various dips intersected by the line of surface. This becomes still more evident on referring to the plan,

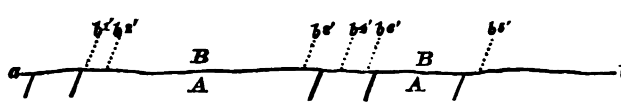


FIG. 17.—Effects of a fault on veins with different dips; plan.

Fig. 17, supposed to be taken at *a b* after the country on the side B had been removed by denudation to the same level. The letters and figures of reference correspond in plan and section, and it will be found on comparing the two that the veins b^1, b^2, and b^5 are shifted to the right, on the side of the dislocation marked B, while b^3 and b^4 are moved to the left; the branch b^6 on the other hand, which does not reach the surface on the side A, appears on the side B at the level *a b*.

It has been already stated that the relative ages of veins and systems of veins in districts where they cross one another, may be ascertained by observing which of them intersect others, or are severally intersected by others; and that the intersection of a vein by another of more recent date is often attended by a displacement or heave of the former. In comparatively rare cases, however, the more recent vein appears to have been displaced by the older one, although this is not in reality the case.

The more recent vein *a* in Fig. 18 would appear to have been displaced by the older one *b*, which it finally intersects. The true explanation of this phenomenon is, however, that the fissure of the vein *a*, following the lines of least resistance, has taken its course for some distance along one of the walls of the older vein *b*, and has then crossed it, without causing any horizontal displacement.

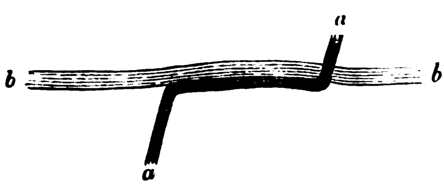
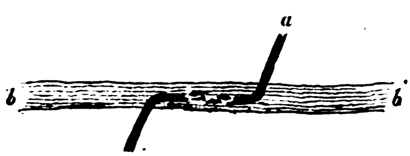


FIG. 18.



FIG, 19.

Veins apparently displaced by older ones.

Instead of forming an angle and following one of the walls of an older vein, the newer one occasionally, although still more exceptionally, enters the older vein by a fissure not extending directly across it, but communicating with longitudinal cracks along the axis of the vein itself, which subsequently unite with a fissure traversing the country on the opposite side. Fig. 19 represents a case of this kind, where the more recent vein *a*, enclosed in the older one, follows for a short distance the course of the vein *b*, by which it would at first sight appear to have been displaced.

When a lode is divided by a fissure resulting in a slide or leap, the movement of the hanging wall is generally downwards along its foot wall. Fig. 20 is a case of this kind, where the dip of the fault and that of the vein are in contrary directions. In Fig. 21 the dip of the vein and that of the fault are seen to be in the same direction.

Mineral veins like beds, are occasionally affected by reversed faults; two examples of these are represented by Figs. 22 and 23. In the first it will be observed that there is a space, in the direction of the movement, between the two portions of the divided lode, which if projected on a horizontal plane would represent a sterile space of which the width will vary with the extent of the displacement.

In Fig. 23 the vein has, on the contrary, been forced upwards

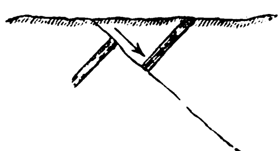


FIG. 20.

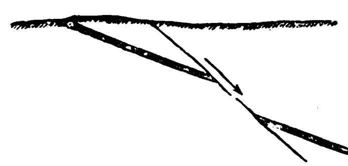


FIG. 21.

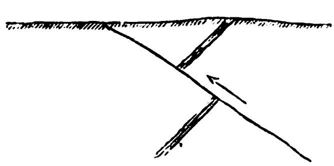


FIG. 22.

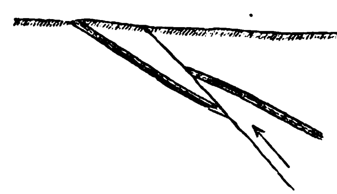


FIG. 23.

Slides or leaps.

in such a way as to overlap itself, and a projection of the raised extremity upon a horizontal plane would show two superimposed lodes over a space, the width of which will depend on the amount of dislocation.

When the throw has been produced by a fissure, of which the position is exactly vertical, the direction in which the movement has taken place can only be determined after a careful study of the sequence of the rocks on both the hanging and foot-walls of the lode, and their correlation with the same rocks where visible in undisturbed ground.

When a vein fissure becomes somewhat abruptly contracted so as to be represented by a mere crack in the country, the lode is said to be *nipped*. Branches which leave a main lode and fall away into the country rock are called *droppers*, while those which, on the contrary, fall into the lode from the surrounding rock are known as *feeders*. The character and direction of these offsets from a vein are carefully watched by the practical miner, who, from their general appearance and position, often forms his opinion with regard to the portions likely to yield the largest amounts of ore.

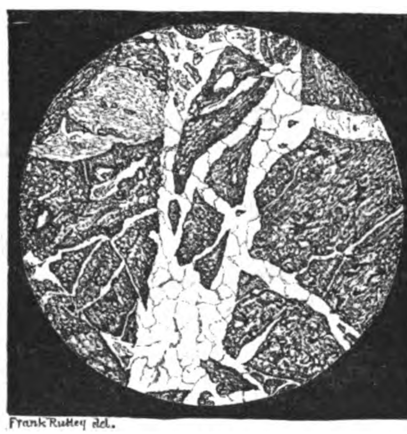
Structure of Veins and Composition of Veinstones.—Speaking generally, the larger proportion of every vein fissure is occupied by *gangue* or *veinstone;* these being the terms applied to the non-metalliferous portions which almost invariably accompany ores of the valuable metals in a vein or lode.

The most constantly occurring substance in veinstones is quartz, which is probably to some extent present in all mineral veins. This quartz is usually either crystalline or crypto-crystalline and contains numerous fluid cavities; it is sometimes also concretionary. Beautiful specimens of crystallized quartz are obtained from the druses, or *vughs*, which are frequently met with in veins. After quartz, carbonate of lime is the mineral which most frequently forms one of the constituents of veinstones; it is commonly crystalline, and often passes into brown spar or dolomite. Fluor spar and heavy spar are also minerals which frequently occur in veinstones. In many cases these, either singly or together, constitute for considerable spaces the entire filling of vein fissures without any admixture of metalliferous ores.

If thin sections of veinstone be examined under the microscope with polarized light, they will be found to consist largely of crystals or crystalline grains; but, to the unassisted eye, they sometimes appear to be compact, or only slightly granular. Through this amorphous or granular ground-mass metalliferous ores are disseminated in patches, laminæ, or crystals; and when crystallized forms prevail, the mechanical constitution of the veinstone is analogous to that which among rocks is known as a porphyritic structure.

Many lodes enclose fragments of the surrounding country rock; these, which are sometimes angular and at others rounded, are cemented together either by ordinary veinstone or by metalliferous ores. The latter was the case at Relistian, in Cornwall, where rounded pebbles of a dark-green chloritic schist were found cemented into a conglomerate by a mixture of oxide of tin, chalcopyrite, and quartz.

It will be remembered that when a fragment of the country, of such large dimensions as to divide a lode into two branches occurs, and these branches subsequently unite upon all sides, the included rock is called a horse. Pieces of country rock in fragments too small to be distinguishable by the unassisted eye, are also frequently enclosed in siliceous veinstones. Fig. 24 represents a section of a veinstone of this class from a lode at Huelgoët, Finistère, France, seen under the microscope. It will be observed that the various disunited fragments of included slaty rock appear to have separated from one another very gradually, and the exact way in which they formerly fitted together is still readily traced. In this instance the fragments of slate are quite unaltered, and their outlines sharply defined. This, however, is not always the case, since in other specimens the



× 25

FIG. 24.—Veinstone, Huelgoët.

enclosed fragments of country are often to a large extent replaced by silica, leaving only a shadowy image of their original forms.

The substitution, in rocks, of silica for other minerals is not unlike the replacement of woody fibre by the same substance in ordinary silicified woods, excepting that in the latter the silica is always more or less hydrated. Examples of this kind of silicification are often observable as capels where the walls of a vein have been subjected to silicifying action. When a mineral vein occurs in crystalline rocks, such as porphyry, thin sections not unfrequently show that portions of the country, now forming part of the veinstone, although to a large extent silicified, still exhibit traces of forms which were originally felspar crystals.

In *brecciated lodes*, as veins made up of broken materials are called, the included fragments, instead of having originally been pieces of the country rock, are in some instances portions of a previously existing metalliferous vein, which has been disrupted by the re-opening of the vein fissure, and its contents reduced to a fragmentary state by the subsequent grinding together of its walls.

In many cases a vein encloses at the same time pieces of the country rock and of veinstone belonging to an older lode; this is shown in Fig. 25, which represents a fragment from a quartzose copper lode at the Knockmahon Mines, Ireland.

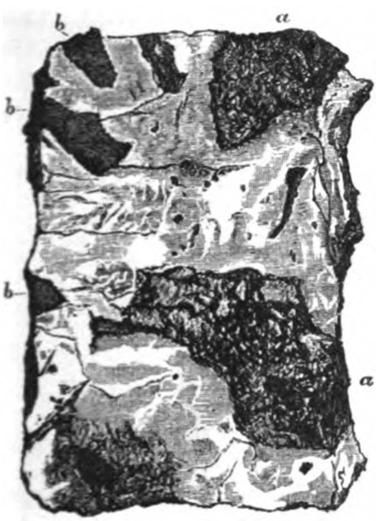


FIG. 25.—Fragment of lode, Knockmahon, Ireland; natural size.

a, Older veinstone with chalcopyrite; b, country rock.

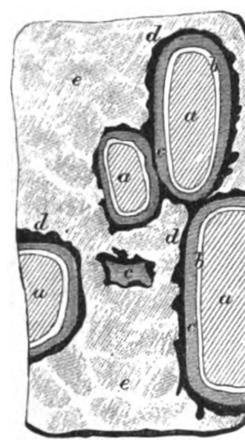


FIG. 26.—Fragment of lode, Bergmannstrost Mine, Clausthal; after v. Groddeck.

a, Older veinstone; b, quartz; c, galena; d, blende; e, calcite.

In place of consisting simply of embedded fragments of older veinstone or of country rock, the inclusions in veins are sometimes covered by regular deposits of other minerals. When metallic sulphides or other ores have been thus deposited, they are known as *ring ores* or *cockade ores*.

Fig. 26 represents an example of the last-named formation from the Bergmannstrost Mine, Clausthal.

When the ores deposited around fragments of included rock have a radial crystalline structure, they are sometimes called *spherulitic ores*.

At Huelgoët the principal lead vein is in part composed of what would at first appear to be a conglomerate, consisting of quartz pebbles cemented together by blende, pyrites, quartz, and galena. On breaking these "pebbles" they are all found to consist of a central nucleus of slaty country rock, surrounded by an envelope of slightly chalcedonic quartz, and only in outward appearance differing from an ordinary quartz pebble in being somewhat less smooth.

Fig. 27 represents one of these pebbles which has been cut through and polished by the lapidary, and which, in addition to a nucleus of dark slate, shows evidence, at *a*, that it has been broken by the movement of the enclosing walls and subsequently re-cemented by a growth of quartz.

The various minerals of which the filling of a vein fissure is made up, are frequently arranged as a succession of plates parallel to its walls. These plates or *combs* are aggregations of crystalline

FIG. 27.—"Pebble," Huelgoët; two-thirds natural size.
a, Line of fracture.

minerals, the separate crystals of which are usually arranged with their longer axes at right angles to the walls of the lode; while their form is more perfectly developed at the ends turned towards its centre than at the other extremity. The ribbon-like structure of *comby lodes* indicates long-continued chemical action, occasionally interrupted, but again renewed under different conditions; the substances deposited on the walls varying with the nature of the minerals held in solution at the time the bands were severally formed. Some parts of a vein may exhibit a comby structure, while others show no trace of any particular arrangement.

Vein fissures frequently bear evidence of having again opened after having become filled with mineral ; the new opening thus formed affording the requisite space for a further deposition of veinstone. In some cases the re-opening of the cavity appears to have been repeated several times in succession, the thickness of each comb indicating the width or progressive widening of the fissure during the time its filling was being deposited. It not unfrequently happens that the re-opening of a fissure has been attended by a grinding together of the walls, resulting in the production of slickensides and flucans. In some lodes the width of the fissure would appear either to have gradually increased or to have remained unaltered during the whole period of its being filled, while successive deposits took place in such a way as to produce a series of bands arranged parallel to one another.

One of the most remarkable examples of symmetrical repetition in a comby lode is presented by the Drei Prinzen Spat Vein, near Freiberg, a portion of which, is represented in Fig. 28. Next

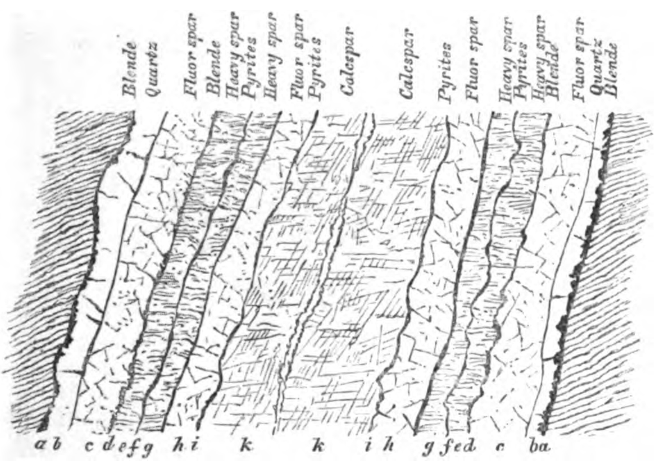


FIG. 28.—Section of the Drei Prinzen Spat Vein, near Freiberg; after v. Weissenbach.

to the walls on each side is a crystallized deposit of blende followed by layers of quartz, succeeded by others of fluor spar, iron pyrites, and heavy spar, &c, as indicated in the figure; each comb on one side having one exactly corresponding to it on the other. The middle portion is occupied by crystals of calcite on either side of a central cavity, the whole showing ten symmetrical repetitions of six different minerals.

Such perfect symmetry is not, however, common, and when it occurs it does not afford convincing evidence that no re-opening of the fissure has taken place, since one might evidently be produced without any perceptible displacement or grinding of the walls.

The combs of the same vein may be symmetrically arranged in one portion of its section, and occur without any degree of symmetry in another.

Fig. 29 represents a transverse section of part of a vein at Huel Mary Ann, near Liskeard, Cornwall, which furnishes an example of a lode in which the layers, which are not numerous, appear to be arranged symmetrically.[1] Here there are, first of all, two walls of killas or clay slate, and then, proceeding from the walls inwards, a layer of chalcedonic quartz, *a*, locally called *cab.* To this follows a layer of vitreous crystallized quartz *b*, next galena *c*, and finally chalybite *d*.

Fig. 30 is a section of the same vein at a short distance from

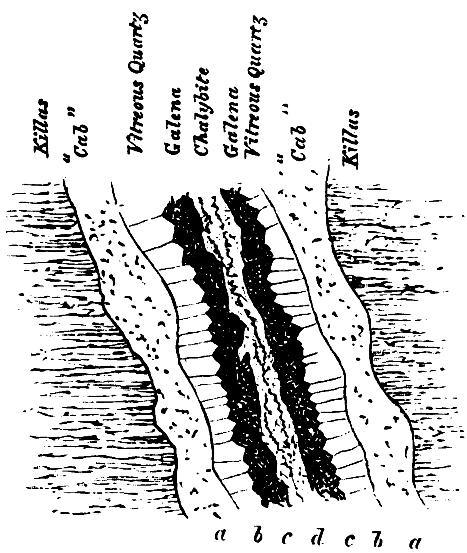


FIG. 29.—Section of vein at Huel Mary Ann; after Le Neve Foster.

the foregoing, where it has a partly combed structure and partly a brecciated one. On the hanging wall the cab, *a*, is traversed by a vein of vitreous quartz, *b*, which crystallizes out in a large vugh; then follows another band of quartz, *c*, while on the foot wall there is a breccia, *d*, composed of fragments of killas and cab cemented together by galena and calcite. In this case the various phenomena connected with the formation of the lode probably occurred in the following sequence :—

Firstly, formation of the fissure, accompanied by a shifting of

[1] C. Le Neve Foster, "On the Lode at Huel Mary Ann, Menheniot,"—*Trans. Royal Geol. Soc. of Cornwall*, vol. ix., 1875, p. 152.

the strata. A succession of empty spaces were left, and some parts were more or less filled by fragments which had fallen from the walls. As might be anticipated, this breccia chiefly occurs on the foot wall.

Secondly, deposition of the cab, which, to a certain extent, filled the fissure and cemented together the fragments from the walls.

Thirdly, re-opening of the fissure; the new line of fracture sometimes traversing the middle of the filling of cab, at others cutting across it, and ultimately following one of the walls of the original fissure. Pieces of the wall and of the previously-

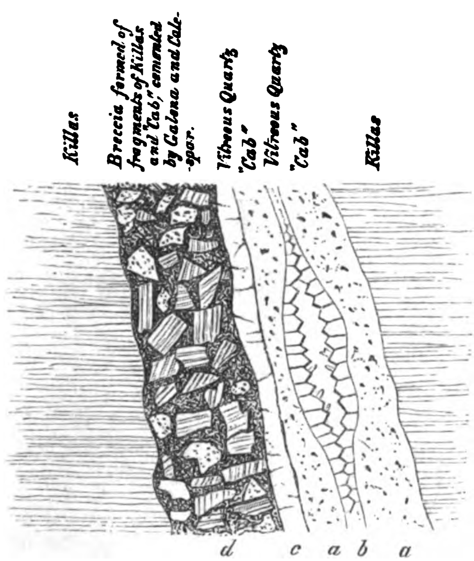


FIG. 30.—Section of vein at Huel Mary Ann ; after Le Neve Foster.

formed cab then fell in, and quartz, galena, chalybite, and calcite were successively deposited in the open spaces.

Fig. 31 is a section of a lode in granite at Carn Marth, near Redruth, one-twelfth natural size, affording a good example of a fissure which has been several times re-opened.[1] It will be observed that each re-opening has been attended by an amount of grinding action between the walls, sufficient to produce a clay parting of considerable thickness. This lode is enclosed in granite, and the dots and patches of black in the figure represent spots and bunches of copper ore.

[1] J. H. Collins, "On the Mining District of Cornwall and West Devon."—*Institute of Mechanical Engineers, Proceedings*, 1873, p. 89.

The arrangement of the various minerals in the combs of a vein is precisely that which would result from their crystallization either from solution or by sublimation; the successive layers are produced by deposits parallel to the walls, while the crystals have their longer axis directed towards the centre of the vein. It would therefore appear that the phenomena observed might be produced in at least two different ways, but this subject will be again referred to when we consider the various theories which have been advanced to account for the formation of mineral veins.

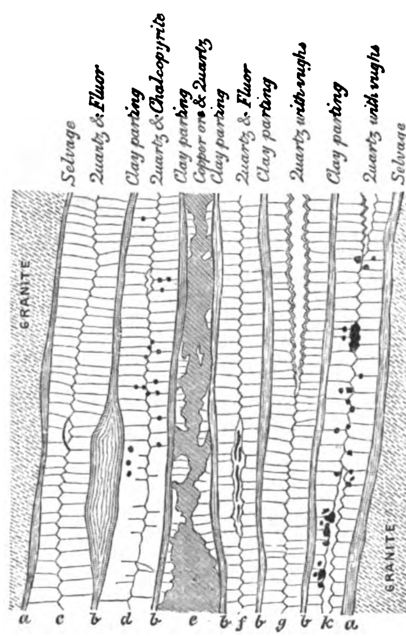


FIG. 31.—Section of vein, Carn Marth.

Distribution of the Ores in Lodes.—In a vast majority of cases the more metalliferous parts of a lode, or those which yield the ore sought in an approximately marketable state, constitute but a comparatively small proportion of the whole, and but few metalliferous veins are sufficiently rich throughout their extent to pay for the removal of the whole of the veinstone. A large proportion of the lode is consequently left standing in the mine, while the richer portions only are taken away and brought to the surface. It is always a matter of considerable uncertainty whether rich deposits of ore may or may not occur in a vein, and no definite opinion can be formed on the subject until a careful study has been made both of the vein and of the neighbourhood in which it is situated. In regions in which parallel lodes, similarly situated, have been extensively worked, the miner profits by the experience thus acquired, and considers there is a probability that like conditions may produce similar results. When, therefore, such lodes exist in any given locality and the position and direction of any courses of ore in one or more of them have been ascertained, there is a probability that the others may contain similar deposits.

It would be of great scientific interest, as well as of the utmost practical importance, if the causes of this unequal distribution of ore could be discovered, and some rule laid down for detecting the position of the richer portions of a lode. Unfortunately, up to the present time, no certain method of doing this has been found, and it is only by a careful study of the district in which a vein is situated that anything like an approximation to this knowledge can be acquired. The conclusion arrived at will be much influenced by numerous almost undefinable facts, and indications, which, although they enable the miner who is well acquainted with a district to direct his operations with a considerable amount of accuracy, would probably lead him to the commission of grave mistakes if applied in a totally different locality. Miners with fixed ideas, resulting from observations made in a limited area, are consequently liable to make serious mistakes when they attempt to apply their experience in distant and totally new localities.

When a mass of ore extends in a lode in the direction of its course, horizontally, in such a way that a gallery or level driven through it for a distance of many fathoms is continuously or almost continuously in rich mineral, and this ore is again met with in levels above and below it, the deposit is known as a *course of ore.* Such courses of ore are sometimes very extensive, as, for example, in the adjoining mines of Huel Seton and Huel Crofty, in Cornwall, where a course of copper ore extended continuously over a length of 225 fathoms, and had an average depth of about fifty fathoms.

In the mining districts of the West of England when a course of ore is spoken of without specifying the metal that is present, the word *copper* is often understood. Thus it is usual to speak of a course of ore, a course of tin, a course of lead, &c. Large masses of ore occurring in the mines of the new world are sometimes called *bonanzas*, but this term is chiefly restricted to deposits containing one of the precious metals.

When deposits of metalliferous minerals assume the form of bands or columns more or less steeply inclined in the plane of a lode, they are known as *shoots of ore* or *chimneys of ore.* The shaded portions in Fig. 32 represent the mode of occurrence of galena at the celebrated Snailbeach Mine, Shropshire, which affords a good example of an ore occurring in shoots. The horizontal extent of a shoot of ore is for the most part somewhat limited, while its persistency in depth is often very considerable. As a general rule, all the ore-shoots in a given vein dip in the same direction, which, most commonly, is also that of the bedding, or cleavage, of the rocks through which the lode passes. The distinction between a course of ore and a

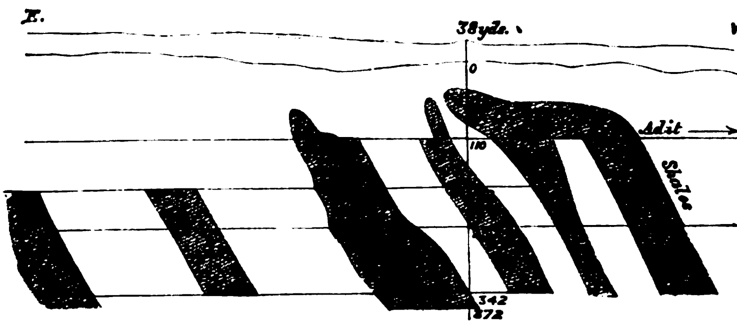


FIG. 32.—Longitudinal section of a portion of the Snailbeach Mine, Shropshire.

shoot, although usually sufficiently definite, is nevertheless, to some extent, vague, since, in extreme cases, the form and character of a mass of ore may represent a sort of passage from the one form to the other. The term, course of ore, may, however, be regarded, generally, as applied to tabular more or less horizontal masses of ore of unusual extent and richness, while the word shoot, which conveys the idea of a workable deposit, is chiefly used as indicating the high inclination and persistency in depth of the ore-bearing portions of a vein.

When a course or shoot of a metalliferous mineral has been discovered in any one of a series of parallel lodes traversing the same country rocks, there is a considerable probability that somewhat similar deposits may be met with in approximately corresponding positions in the other lodes of the group. Inasmuch as the more valuable deposits found in a series of parallel lodes are usually enclosed in the same country rock, it follows that these, as well as the lodes themselves, will be approximately parallel; hence the aphorism of the miner, *ore against ore.*

This arrangement of the metalliferous contents of a series of veins will be understood on referring to Fig. 33, in which *a, b, c,* are veins, and *d* the country rock; the deposits of ore being indicated by lines of shading.

When the ore in a lode occurs in detached patches it is said to be *bunchy*, and each separate patch is called a *bunch*. Although, according to this definition, it may be sometimes difficult to distinguish between a small course of ore and a large bunch, the terms are usually well understood and are regarded as being fairly definite. It has been observed that in *bunchy lodes*, the bunches, like shoots of ore, have a tendency to arrange themselves in accordance with the dip, or cleavage, of the enclosing rocks,

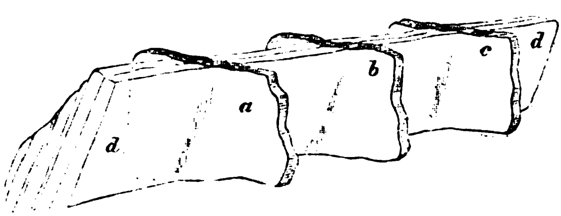


FIG. 33.—Ore deposits in parallel lodes.

In many cases the ores in a lode occur neither in courses, shoots, nor bunches, but are disseminated in a crystalline or granular form throughout the veinstone. Lodes in which the ores thus occur are, by Cornish miners, known as *dradge lodes.*

The conditions under which deposits of ore occur in mineral veins vary in different districts, and it would be impossible to lay down anything beyond very general rules relative to this subject. Attention will, however, be directed to these local peculiarities when the various districts in which they occur are specially described.

It may, however, be stated, speaking generally, that those lodes are most productive whose dips approach most nearly to the perpendicular, and that the most productive portions of lodes are usually enclosed between walls possessing a moderate degree of hardness. This may, to some extent, be accounted for by the fact that accumulations of débris from the wall rock will less frequently take place in the fissures of nearly vertical lodes than in those of which the inclination approximates more nearly to the horizontal. It will be obvious also that a larger number of fragments will fall into a vein fissure from a soft splintery hanging wall than from a moderately hard and sound one.

Miners are aware that in all metalliferous districts lodes following certain known directions are more frequently productive than those which vary only a few degrees from that course. This may, perhaps, be accounted for on the assumption that fissures formed during periods when salts of various metals were held in solution by waters circulating through them, will become charged with ores of those metals. Fissures opened at subsequent periods will, in their turn, become filled with ores of metals resulting from the salts at that time circulating in solution, and which differ from, and have replaced those present during the period the first system of vein fissures was being filled. On the other hand, fissures may be formed at an epoch during which the circulating waters contained no metallic salts, and in that case the resulting veins will be non-metalliferous.

M. Moissenet, who has studied the metalliferous veins of different mining districts, and especially those of Cornwall, with reference to the relations existing between their productiveness and their direction, has endeavoured to explain the observed phenomena in accordance with M. Élie de Beaumont's theory of the *Réseau pentagonal*. The assumption of the simultaneous elevation of parallel mountain chains is however not generally received by geologists, and the conclusions arrived at by M. Moissenet are not always in accordance with established facts.

Outcrop of Lodes.—The outcrops and upper portions of metalliferous veins are often found to have undergone a series of chemical changes by which they have ultimately become transformed, more or less completely, into siliceous peroxide of iron and hydrated ferric oxide. This product of decomposition receives various names in different mining regions. By the Cornish miner it is called *gossan*; in France it is known as *chapeau de fer*, and in Germany as *eiserner Hut*. The *pacos* or *colorados* of South America are essentially similar productions, which, like all vein-cappings, vary to some extent in colour and composition.

The ferric oxide in these outcrops is most frequently derived from the oxidation of metallic sulphides containing a large proportion of iron, such as ordinary iron pyrites, magnetic pyrites, chalcopyrite, &c., and being disseminated generally throughout the mass, it imparts to it its usual predominating red or brown colour. In some cases the ferruginous capping of lodes is a result of the decomposition and peroxidation either of siderite, or of bitter spar containing iron.

Gossans often extend to a depth of many fathoms, but are seldom found much below the drainage level of the district. They sometimes contain valuable metals, such as gold, silver, copper, and lead, which were originally associated with the minerals from which the ferric oxide was derived. The gold is invariably found in the metallic state; while the other metals may occur in combination with oxygen, chlorine, iodine, bromine, &c., or with carbonic, sulphuric, or phosphoric acids. Arsenic is also one of the metals often present in ferruginous outcrops, and native copper is not of unfrequent occurrence. With increasing depth these products of decomposition gradually pass over either into sulphides, or into spathic ores, &c. In the same way the auriferous pyrites occurring near the outcrop of gold veins ordinarily becomes transformed into pulverulent oxide of iron, from which gold is readily separated either by washing or amalgamation. From this cause many auriferous quartz veins have, when worked near the surface, been found to readily yield their gold, but after the water-level has been reached, sulphides have made their appearance, and much difficulty has been experienced in treating the auriferous rock.

The presence of such products of decomposition at the outcrop, has, at all times and in all countries, been regarded by miners as affording an indication that a vein may, in depth, prove abundantly metalliferous. It must, nevertheless, be borne in mind, that the decomposition of common pyrites, and of various other ferriferous minerals, gives rise to the formation of a gossan differing from that which results from the oxidation of chalcopyrite chiefly in being somewhat more compact. The occurrence of gossan may consequently be regarded as indicating the probable presence of a metallic sulphide, and where one metallic sulphide is present in large quantities, others will probably be found.

When the ferruginous capping of a lode contains, as is often the case, other metals in addition to iron, their presence may be regarded as adding considerably to the probability of the occurrence of their ores at a greater depth. The wall rocks on either side of gossan outcrops are usually much decomposed and softened, by the action upon them of the various solutions resulting from chemical changes which have taken place within the vein.

Grouping and Sequence of Minerals in Lodes.—Among the various substances constituting the filling of vein fissures, certain minerals are more frequently associated with one another, than they are with others. In this way pyrites and chalcopyrite, blende and galena, wolfram and cassiterite, heavy spar and fluor spar, &c., are found together. These combinations, which are sometimes very complicated, are not always consistent, and as the number of minerals which occur in veins is extremely large, it would be very difficult to enumerate all the different combinations of this kind which have been observed. Definite associations of ores and veinstones are sometimes called *ore formations, vein formations, vein types,* &c. The grouping together of certain mineral species in metalliferous veins may possibly be due to the common solubility of these ores in the same medium, and to their ability to deposit crystals from the same solutions under similar conditions. Although it would be difficult to enumerate all the known associations of metalliferous ores in lodes, the table on p. 55 will afford a general idea of the more simple groupings which they affect.[1]

The succession of the various minerals constituting either a series of dissimilar combs, or the successive crystallizations of geodes or druses, has long attracted the attention of the scientific miner. Many years ago v. Weissenbach observed the following sequence of vein-material from the wall rock to the centre in the system of lodes which occur in the district around Brand, a few miles west of Freiberg.[2]

1. Quartz veins containing iron pyrites, black blende, and galena, with mispickel, affording a moderate proportion of silver.

2. Diallogite and brown spar, in addition to the above-mentioned ores, which are rich in silver and contain patches of argentiferous tetrahedrite, and other rich silver ores.

3. Spathose iron ore, fluor spar, and heavy spar, over which a greyish variety of brown spar has sometimes been deposited. The ores of group 2 are present, but in less quantities, and the galena disseminated through the heavy spar contains but little silver.

4. Calcite, occasionally enclosing rich silver ores, but without the ores of group 1.

The sequence of the various minerals constituting metalliferous

[1] Bernhard v. Cotta, " Die Lehre von den Erzlagerstätten," 2nd edition, Freiberg, 1859, p. 37. American Translation, 1870, p. 14.

[2] C. G. A. v. Weissenbach, "Abbildungen merkwürdiger Gangverhältnisse aus dem sächsischen Erzgebirge," Leipzig, 1836, p. 31.

veins has also been examined by both Breithaupt and Henwood, neither of whom was enabled to deduce from his observations any general law of succession. With comparatively few exceptions, however, all the various series of minerals in veinstones begin

ASSOCIATION OF ORES IN METALLIFEROUS VEINS.

Two Members.	Three Members.	Four or more Members.
Galena, blende.	Galena, blende, iron pyrites. (Silver ores.)	Galena, blende, iron pyrites, quartz; *and* spathic iron ore, diallogite, brown spar, calc spar; *or* heavy spar.
Iron pyrites, chalcopyrite.	Iron pyrites, chalcopyrite, quartz. (Copper ores.)	Iron pyrites, chalcopyrite, galena, blende; *and* spathic iron ore, diallogite, brown spar, calc spar; *or* heavy spar.
Gold, quartz.	Gold, quartz, iron pyrites.	Gold quartz, iron pyrites, galena, blende; *and* spathic iron ore, diallogite, brown spar, calc spar; *or* heavy spar.
Cobalt and nickel ores.	Cobalt and nickel ores, and iron pyrites.	Cobalt and nickel ores, iron pyrites; *and* galena, blende, quartz, spathic iron ore, diallogite, brown spar, calc spar; *or* heavy spar.
Tin ore, wolfram.	Tin ore, wolfram, quartz.	Tin ore, wolfram, quartz, mica, tourmaline, topaz, &c.
Gold, tellurium.	Gold, tellurium, tetrahedrite (Various tellurium ores.)	Gold, tellurium, tetrahedrite, quartz; *and* brown spar; *or* calc spar.
Cinnabar, tetrahedrite.	Cinnabar, tetrahedrite, pyrites. (Various ores of quicksilver.)	Cinnabar, tetrahedrite, pyrites, quartz; *and* spathic iron ore, diallogite, brown spar, calc spar; *or* heavy spar.
Magnetite, chlorite.	Magnetite, chlorite, garnet.	Magnetite, chlorite, garnet, pyroxene, hornblende, pyrites, &c.

with a layer of quartz, but beyond this it is found that, even in the same district the different minerals constituting subsequent deposits frequently vary, not only in the order of their succession, but also in their composition.

The following table has been constructed from a much longer one by W. J. Henwood, in which he summarizes the results of his personal observations relating to the order of succession of the minerals in various lodes in Cornwall.[1]

POSITIONS OF CONSTITUENT MINERALS IN CERTAIN LODES IN CORNWALL.

Rock.	Substance next adjoining the rock.	Substance next to that which adjoins the rock.	Minerals adjoining that in the last column.	Minerals adjoining that in the last column.	Localities.
Granite.	Quartz.	Quartz.	Chalcedony.	......	Pedn-an-drea.
	,,	,,	Arseniate of iron.	......	Huel Gorland.
	,,	,,	Wolfram.	......	St. Michael's Mount
	,,	,,	Uranite.	......	Gunnis Lake.
	,,	Oxide of tin.	Tungstate of lime	......	Huel Friendship.
	Earthy brown iron ore.	Vitreous copper ore.	Earthy black copper ore.	......	Huel Jewel.
Green-stone.	Quartz.	Stalactitic quartz.	Quartz.	......	Huel Edward.
	,,	Quartz.	Aragonite.	......	Levant.
	,,	,,	Hydrous oxide of iron.	......	Restormel.
	,,	Chlorite.	Oxide of tin.	......	Huel Vor.
	,,	Arsenical pyrites.	Arsenical pyrites.	......	Huel Unity Wood.
	,,	Chlorite.	Copper pyrites.	Mineral pitch.	North Roskear.
Clay slate	Quartz.	Quartz.	Copper pyrites.	Quartz.	East Crinnis.
	,,	,,	Copper pyrites.	Copper pyrites.	United Hills.
	,,	Iron pyrites.	Carbonate of iron.	Spathose iron ore.	Virtuous Lady.
	,,	Galena.	Galena.	Quartz.	Huel Rose.
	,,	Copper pyrites	Sulphide of bismuth.	......	Fowey Consols.
	,,	Quartz.	Blende.	Fluor spar.	Polberrow.
Elvan.	Oxide of tin.	Oxide of tin.	......	......	Wherry Mine.
	Quartz.	Earthy brown iron ore.	Blue carbonate of copper.	......	Ting Tang.
	Earthy brown iron ore.	Native copper.	......	......	Huel Buller.
	Quartz.	Vitreous copper ore.	......	......	Ting Tang.
	,,	Red oxide of copper.	......	......	,,
	,,	Chrysocolla.	......	......	,,

The most recent investigations relative to this subject are those lately published by Sandberger on the paragenesis of the minerals constituting the veins at Schapbach, in Baden. In this mine two distinct lode formations are developed on the course of the Friedrich-Christian Vein where it traverses the gneiss, namely the Schapbachite, or bismuth-silver-ore formation, represented by the so-called "Hard Branch," and the coarse-copper and lead-ore-bearing fluor-spar-pyrites formation.

[1] *Trans. Royal Geol. Soc. of Cornwall*, vol. v. 1843, Table C, facing p. 214.

The succession of the different minerals contained in both these formations has been carefully worked out, and numerous sections across the veins at different points are given. A comprehensive table is also furnished showing the sequence of the various *secondary* minerals resulting from the decomposition of the *primary* or normal ores, &c., originally deposited in the vein fissure. In this case, as in those already quoted, there is great irregularity with regard to the succession of the various deposits, but in order to render this obvious it will be sufficient to give the results of Sandberger's examination of the Hard Branch only:

FRIEDRICH-CHRISTIAN VEIN.—PARAGENESIS OF HARD BRANCH.[1]

a. 1. Decomposed granular banded gneiss, with reddish felspar and whitish mica.
2. White quartz, passing into greyish hornstone and milk-blue chalcedony, with angular fragments of the country rock, disseminated Schapbachite, galena (I), and copper pyrites (I).
3. Quartz $\infty R. \pm R.$
4. Galena $\infty O \infty.$ O (Twinning on O). Native bismuth $-2R.0R$, in very small crystals in the rarely-occurring druses.

b. 1. Gneiss (as above).
2. Compact quartz and chalcedony, with strings of Schapbachite an inch wide, and nests of massive copper pyrites (I) and crystals of iron pyrites $\left(\frac{\infty O2}{2}. \infty O \infty\right)$.
3. Roselite in translucent blebs in fissures, coating quartz and iron pyrites.

c. 1. Grey hornstone with disseminated Schapbachite and galena (I), copper pyrites (I), and iron pyrites (I).
2. White quartz ($\infty R. \pm R$), galena (I) $\infty O \infty.O$).
Native bismuth ($0R. -2R$), bismuth glance occurring only in druses, in aggregates of very small acicular crystals.

d. 1. Whitish gneiss.
2. Grey quartz with Schapbachite and galena (I), and copper pyrites (I).
3. White quartz, with numerous impressions of cubes of fluor spar.
4. White quartz in crystals (∞ R. $\pm R.$).

e. 1. Whitish gneiss.
2. Gray quartz, with Schapbachite and galena.
3. Coarse foliated calc spar (I), crystallized in large scalenohedra (R^3) in druses, but mostly corroded and earthy or dull.

f. 1. Whitish gneiss.
2. White compact quartz.
3. Fluor spar (I) pale green, mixed with calc spar (I) and coarse-grained galena.

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[1] Fridolin Sandberger, "Untersuchungen über Erzgänge," Part I., p. 86, Wiesbaden, 1882.

g. 1. Quartz (II) in larger crystals, with galena.
2. White calc spar (I) (R^3).
3. Quartz (IV) and copper pyrites (III) in thin crusts.

h. 1. Quartz (II) in larger crystals, with milk-white roundish enclosures.
2. Copper pyrites (II) in twins.
3. Brown spar (R).
4. Calc spar (II) ($\infty R . R^3 . -\frac{1}{2}R . R$).

i. 1. Quartz (II) in larger crystals.
2. Calc spar, in sheaf-life aggregates of scalenohedra (R^3) an inch long, superficially altered into chalybite, encrusted and penetrated by
3. Quartz (III) pseudomorphous after barytes.
4. Calc spar (II) in small groups of crystals ($\infty R . -\frac{1}{2}R$).
5. Copper pyrites (III) crystallized, with small crystalline aggregates of quartz (IV).

k. 1. Compact quartz with angular fragments of gneiss, and disseminated galena and copper pyrites (I).
2. Fluor spar in rough yellowish cubes, in regular intergrowths with quartz (III) after barytes.
3. Calc spar (II) ($\infty R . R^3 . -\frac{1}{2}R$).
4. Copper pyrites (III) crystallized.

In the foregoing table, when a mineral has been formed at only one period in the history of the lode, no large numeral is affixed. The numbers I, II, III, and IV, indicate four successive stages of deposition for each mineral, but they do not refer to any particular band or contemporaneously formed pair of bands in the lode. These latter are indicated by the small numerals arranged under the different sections *a*, *b*, *c*, &c., in the table of paragenesis. The sections show the contents of the lode at certain spots, selected as typical of the differences occurring successively along its course.

The various minerals of which metalliferous veins are composed do not always, even in the same lode, occur in a similar order of succession, and when the same minerals are found in corresponding order in different veins, it by no means follows that they are of equal geological age. Metalliferous minerals occur in veins of every age, and the same minerals are sometimes found in a similar order of succession in those belonging to very different periods; such series being not unfrequently repeated more than once in the same vein. In such cases, similar processes of formation appear to have been periodically repeated.

These successions of mineral deposits cannot therefore be regarded as characteristic of particular geological periods, neither must their nature be considered as dependent on their age. The same periods have not everywhere produced similar combinations or successions, and different periods totally dissimilar ones; consequently, it is not possible from the nature of the mineral combinations and successions which occur in a given vein to determine its geological age. In the case of vein fissures formed at different periods, the mineral deposits which take place will depend upon the nature of the substances dissolved in the waters circulating through them at the time of their formation. In the same locality the nature of these solutions has changed from time to time, while similar solutions have re-appeared at certain intervals which have no known general connection with geological time. These changes have been confined to comparatively limited areas, and are not believed to have affected all veins of the same age.

In addition to the minerals originally deposited in vein fissures during the progress of filling, lodes often contain other mineral substances which have been derived from these original deposits by their decomposition and a new arrangement of their constituents. Secondary formations of this kind, for the most part, constitute a very small proportion only of a lode, and occur chiefly near its outcrop and in the vicinity of its intersection by other veins. In this way, in addition to oxide of iron derived from the decomposition of sulphides, the gossans forming the outcrops and shallower portions of many lodes frequently contain massicot, cerussite, anglesite, pyromorphite, wulfenite, &c., resulting from the alteration of galena; and cuprite, melaconite, malachite, and azurite from the decomposition of chalcopyrite.

The formation of these secondary minerals can however be generally traced to well-known chemical reactions, and is therefore quite distinct from the agencies by which the deposition of the original vein material was accomplished.

The occurrence in lodes of minerals exhibiting pseudomorphic forms, produced by their deposition in moulds left by the removal of crystals of other substances, and the presence, in drusy cavities, of stalactites of calcite, quartz, pyrites, &c., indicate that a partial decomposition and re-arrangement of some of their constituents has been effected by the action of water at comparatively low temperatures.

The water now issuing from the back of one of the cross-cuts at Dolcoath deposits in considerable quantities a soft, greyish-brown precipitate, *iron sinter*, which frequently assumes stalactitic forms. Similar incrustations, although generally less abundant, are found in nearly all deep mines wherever water issues from the vicinity of a vein and flows over the surface of the adjacent rock.

Two analyses made of air-dried specimens of this substance afforded the following results:—

	I.	II.
Water { combined	12·77	11·45
Water { hygroscopic	15·90	15·20
Ferric oxide	36·30	37·75
Manganic oxide	trace	trace
Arsenic acid	32·47	32·55
Arsenious acid	trace	·68
Sulphuric acid	2·65	2·52
	100·09	100·15

No. I. is an analysis of this deposit made in my laboratory; No. II. is that of another specimen, made by Mr. Dugald Campbell.

Influence of Depth upon Lodes.—For a long time there appears to have been an impression that lodes are productive to a certain depth only, and that all below is barren and without value. The earlier miners in California were so fully impressed with the idea that the outcrops were more productive than the deeper portions of the same veins that when the quartz ceased to afford remunerative results, they seldom proceeded to any considerable additional depth before suspending their operations. Within the last thirty years, however, experience has entirely changed their opinion upon this subject, as deeper workings have led to the conclusion that there is no evidence tending to indicate a progressive falling off in the yield of gold.

Auriferous veins are always variable in their yield, and it may be assumed that those which at the surface afforded evidence of the presence of gold first claimed the attention of the miner. These, after having been worked to a more or less considerable depth, ultimately became unproductive, and although further prosecution of the operations might have led to fresh discoveries, the miner, who was usually without capital, soon transferred his operations to some other outcrop showing visible gold.

Another reason for the prevalence of this belief among the earlier miners may be traced to the fact, which has been previously mentioned, that gold is almost invariably associated with iron pyrites and other metallic sulphides, and these becoming decomposed, near the surface, liberate the gold, which is readily collected by washing and amalgamation. In the deeper portions of a vein these sulphides remain undecomposed, and although an equal amount of gold may be present, the results obtained by the miner are less satisfactory. With improved machinery and better methods of treatment, this difficulty has now to some extent disappeared, although it is well known that the gold liberated by the natural decomposition of pyrites can be very easily collected.

The working of mines is more easily and more cheaply conducted near the surface than at more considerable depths, and as the difficulty and cost increase with the progress downwards, horizontal explorations on the strike are, in the aggregate, much more extensive than are those upon the dip of lodes. When at a given depth a lode or shoot of ore has temporarily ceased to be productive, it frequently happens that any additional sinking would necessitate the erection of more powerful machinery, and hence there is a greater tendency to drive levels than to sink shafts. Statements relative to the entire disappearance of lodes in depth must therefore be received with caution, since, had the workings been continued, the vein would probably have again been found and have again become productive. Comparatively few mines have reached four hundred fathoms, but there is reason to believe that true veins extend to depths to which the miner will be unable to follow them.

According to Lieber, many lodes both in North and South Carolina appear to contain gold near the surface, while lower down they yield lead and copper ores with but little gold. The succession from the top downwards is stated to be gold, lead, copper; but his observations were not made in each case on the same lode, and the conclusions at which he arrives are at variance with those of other observers. Messrs. Shepard and Eights state that gold is present in these veins at all depths that have as yet been reached, but is easily recognizable in those parts only where the decomposition of sulphides has resulted in the formation of gossan and the liberation of gold. My own examination of the region in question would lead me to agree with the last named observers.

Many of the lodes in Cornwall which in the shallower levels yielded an abundance of copper ores, now at greater depths afford large quantities of tin oxide; but whether copper ores again occur still deeper is unknown. If it were established that changes in the composition of lodes took place at approximately fixed depths from the original surface, the phenomena might be regarded as due to the constantly increasing temperature and pressure resulting from greater depth; but up to the present time we are without any reliable data bearing upon this subject.

Influences of the Country Rock.—Every one who has written upon the mining districts of Cornwall, has remarked that almost the whole of the mineral weath of that county occurs within a distance of some two or three miles on each side of the junction of granite and clay slate or killas. According to W. J. Henwood, who carefully studied the subject, no part of this line appears, however, to have been notably more productive than any other part of the same extent within the distance mentioned.[1] And although lodes not uncommonly run for many fathoms with granite on one side and slate on the other, or with either of these rocks forming one wall and elvan, *quartz-porphyry*, the opposite one; yet the portions of the lodes thus contained between dissimilar rocks have not generally been found to be the most productive. The metalliferous contents of lodes appear also to be not only affected by the mineral composition of the contiguous rocks, but in some degree also by their position and mechanical structure.

Whether the rocks be granite, slate, or elvan, their hardest portions are always quartzose, and in these the lodes are seldom rich. In granite, a fine-grained rock, locally known as *whetstone*, is always an unfavourable indication, while if that which is of a coarser texture contains large white and sharply-defined crystals of felspar, the indication is equally unfavourable.

If, on the contrary, the grain of the rock be neither very fine, on the one hand, nor particularly coarse on the other, while the enclosed crystals of felspar have a greenish, brownish, or pinkish tint, with indistinct outlines merging into the ground-mass, quartz, mica, and sometimes schorl being present, the character of the rock is considered to be a favourable one, and lodes enclosed in it may be expected to be fairly productive, especially of tin ore.

A hard, fine-grained quartzose elvan that contains schorl, either diffused as a colouring matter only, or in groups of radiating crystals, is not a favourable country rock, as the lodes in such elvans frequently divide and split up into innumerable branches, which reunite when they approach softer and more felspathic varieties of the same rock. The varieties of elvan most favourable to riches differ slightly as regards tin and copper ores. Lodes are sometimes tolerably productive of the former, even when split into strings

[1] *Trans. Roy. Geo. Soc. of Cornwall*, vol. v. 1843, pp. 219 225.

and enclosed in a glassy quartzose elvan. In the case of copper ores, on the contrary, unless the rock be soft, and to some extent decomposed, the lodes dwindle and become unprofitable.

In the neighbourhood of the St. Just and St. Ives copper mines the rock is a fine-grained hornblendic slate containing felspar. A decomposed slaty rock of a pale greyish hue passing into a dull white, and sometimes marked between the laminæ with bluish spots, accompanies the richer portions of the copper lodes in the greater part of the Gwennap district. The same or very similar rocks occur in the neighbourhood of St. Agnes, in some portions of the St. Austell district, and in the neighbourhood of Callington. In these tin ore is by no means abundant, although it is found in the shallower parts of some of the lodes. Copper ores not only occur in this rock, but have been plentiful in the same lodes after leaving it and entering a dark-blue quartzose slate. In far the greater number of instances, however, the riches dwindle or suddenly disappear with this change of the country rock. In some parts of the Gwennap district, a slate of a reddish colour is regarded as being equally unfavourable to the yield of the lodes by which it may be intersected.

In many of the most productive mines of Western and Central Cornwall, and generally throughout the Tavistock district, copper ores, chiefly occurring as copper pyrites, are found in a deep-blue clay slate having a glassy or silky lustre, and opening in thick horizontal joints which coincide with the planes of cleavage. Lodes in this rock do not usually contain tin ore, and if the slate assumes a deeper hue the copper ores are replaced by iron pyrites; while if the rock becomes quartzose, even the iron pyrites itself disappears.

Wherever tin ore is abundant, the slate is of a tolerably uniform character, being deep-blue in colour with occasionally a somewhat greenish tinge, and a gloss or silkiness on the surface of the cleavage planes. A diminution in the depth of colour, and a softening in the texture of the rock, are considered unfavourable indications. The lodes which afford lead ore occur in bluish or greyish slates, and are generally situated at considerable distances from the granite.

With regard to the mechanical structure of rocks, it has been observed that, when in granite, slate, or even in elvan, the joints nearly parallel to the course of a lode fall towards it in descending, it may be regarded as a favourable indication. On the other hand, when such joints diverge from the lode as they go downwards, it is generally considered to be an indication of poverty. Many joints traversing a lode appear to exercise an unfavourable influence upon it, and a course of ore is sometimes cut completely off by a joint running across the lode. In slates, whenever they become quartzose, their cleavage planes are almost invariably much curved or contorted, and the rock is more than ordinarily fissile; such conditions are generally considered unfavourable to the presence of large deposits of ore. When, on the contrary, the planes of cleavage are not distinctly curved, and the rock exhibits a thickly lamellar structure, the lodes passing through it may be expected to be fairly productive. All these indications are, however, extremely local and often confined within very narrow limits, since in the same rock there is frequently an alteration of the lodes as soon as the character of the surrounding country becomes slightly modified.

In the north of England, where the lead veins are situated in regions of Carboniferous Limestone, a singular dependence is observed between the contents of a vein and the nature of the country rock. In Cumberland, the veins divide limestones, sandstones, and shales, and these are brought into various opposition to one another by the displacements which accompany nearly all the veins. A vein is sometimes productive of lead ore under all circumstances of opposition in the enclosing rocks. When limestone forms the walls, its productiveness is usually at the maximum, and schist, and solid sandstones, likewise enclose productive veins; but they are generally contracted in width and impoverished in their contents whenever they are included between walls of slate, and even when one wall only is occupied by that rock the same effect is frequently observed.

In Derbyshire, the veins pass through the Mountain Limestone, and often through its associated igneous rocks, as well as across the various accumulations of shales and sandstones. The lead ore generally, but not always, occurs in the limestone series and most abundantly in the upper portions of it. The igneous rocks, *toadstones*, are sometimes dense, hard traps, while at others, though originally vesicular, the vesicles may be now filled by various infiltrated minerals; they are generally regarded as unfavourable to the production of the enclosed veins. The Derbyshire miners were formerly of opinion that veins do not traverse these toadstones or *blackstones*, as they are sometimes locally termed, but it is now well known that the true fissure veins, or *rakes*, pass through these igneous rocks as well as through the limestones, but that where they constitute the walls of the vein, lead ore is usually absent.

Among the limestones themselves, certain beds are considered more favourable than others as walls to lead veins, and the presence of dolomite is always regarded as an unfavourable indication. Although lead veins are frequently continued through certain shales overlying the limestones, which sometimes contain a considerable amount of carbonaceous matter, veins so enclosed are seldom productive. Many of the smaller metalliferous veins in the Derbyshire limestones are, in point of fact, merely joints in the rock which have received a deposit of lead ore of sufficient importance to induce the miner to follow them in his workings. In Alston Moor, Teesdale, and Swaledale the upper thick limestone is far the richest in lead ore.

In the district around Freiberg the lodes producing silver ores are generally enclosed in gneiss. This rock, which is divided into many different varieties, is traversed by dykes of porphyry and greenstone, and passes into mica schists containing beds of limestone, but v. Cotta states that the miners attach little importance to any of these variations of the country rock. The gneiss of the Erzgebirge may be divided into two principal varieties, namely, the common *grey gneiss*, and the *red gneiss*, so called because its felspar has a red colour. Both the grey and the red gneiss vary considerably in composition and texture, and it sometimes becomes difficult to determine whether a particular modification should be classified with the grey gneiss or with the red. The typical red gneiss would appear to present all the characteristics of an igneous rock, which is never the case with the normal grey gneiss of the Freiberg district. The grey gneiss contains from 64 to 67 per cent. of silica, and is composed of orthoclase, a small proportion of oligoclase with quartz, and much dark-coloured mica. The red gneiss contains from 74 to 76 per cent. of silica, and consists of orthoclase, quartz, and a little nearly colourless mica. According to v. Cotta and Müller, throughout the Erzgebirge the grey gneiss appears to exercise a more favourable influence on the metalliferous contents of the lode than the red gneiss, which contains comparatively few metalliferous veins.[1] It, however, appears that there are numerous intermediate grades between the two extremes which cannot with certainty be assigned to either variety. Müller's generalizations must consequently lose much of both their practical and scientific importance.

At Kongsberg, in Norway, the mines are situated in gneiss and crystalline schists, of which the district for a length of about a hundred miles and a width of some fifty miles is chiefly composed. Certain belts or zones of these crystalline rocks, known as *fahlbands*,

[1] B. v. Cotta and H. Müller, "Gangstudien," vol. i. 1850, p. 209.

are of considerable length and breadth, and are impregnated with finely divided sulphides of iron, copper, and zinc, with sometimes also those of lead, cobalt, and silver. The iron pyrites is often to some extent decomposed, giving rise to the formation of hydrated ferric oxide, which is locally regarded as an indication of the presence of silver ores. In the Kongsberg district there are several of these fahlbands, parallel in strike and inclination with the other gneissoid and schistose rocks of which they form a member. These fahlbands are themselves traversed by metalliferous veins containing silver and other ores, which are never productive except where they intersect a fahlband. In this instance it would appear that the impregnation of the veins with metalliferous minerals is directly dependent on the nature of the enclosing rock, rendering it probable that the metalliferous minerals were originally derived from the fahlbands, from which their removal and subsequent concentration in lodes have been effected by chemical agencies.

The foregoing and many similar examples of the influences exercised by country rocks upon the lodes passing through them have been long known as isolated facts, but the recent investigations of Sandberger and others have thrown much additional light upon the subject, and have invested it with a significance which it did not previously possess. The results of these investigations will be stated, and their bearing upon the productiveness of lodes discussed, when we consider the various theories which have been advanced to account for the formation of metalliferous veins.

Palæontology of Mineral Veins.—Mr. Charles Moore, who paid much attention to this subject, found that many of the clays or flucans associated with the lead lodes in Carboniferous Limestone enclose numerous fossils of Carboniferous, Permian, Rhœtic, and Liassic age. He, moreover, entertained the opinion that veins of this class are of purely marine origin, and that the various organisms which they contain were deposited in open fissures existing in the sea bottoms of the several periods to which the fossils severally belong.[1]

It would appear however far more reasonable to suppose that, in the majority of cases, the various organisms which have from time to time been discovered in veins had already become fossilized when they were transported by the agency of water from higher ground into the various fissures of the limestone. The investigations of Mr. Moore comprehended the examination of materials derived from veins and vein fissures in the Carboniferous Lime-

[1] *Report of the British Association for the Advancement of Science for* 1869, p. 360.

stones of Wharfedale, Wensleydale, Weardale, Teesdale, Swaledale, Alston Moor, Keswick, North and South Wales, and parts of Somersetshire.

In the Carboniferous Limestone districts of Holwell and Frome, Rhœtic and Liassic organisms form a large proportion of the fossils present in the veins, and the same is the case throughout the Mendip range and in South Wales.[1] In North Wales and in the north of England, on the contrary, Carboniferous remains are most frequent, while those of later age are exceptions, some of these being Entomostraca of Permian species. According to Mr. Moore, fossil remains are of more frequent occurrence in veins traversing the Carboniferous Limestones of the Mendip Hills than they are in those of any other locality which he examined; but, with one exception, he never failed to find fossils wherever he sought for them in veins enclosed in limestones belonging to this formation.

Age of Mineral Veins.—True veins or lodes must in all cases necessarily be of more recent origin than the rocks in which they are enclosed, and when one vein crosses another it evidently must have been formed subsequently to the vein so intersected. In this way the relative ages of different veins occurring in a given district may often be determined without much difficulty, but to assign the formation of any vein or group of veins to a definite period of geological time is frequently more difficult. Sometimes also it is not easy to determine whether or not lodes are older than certain neighbouring rocks which have not been intersected by them. When, however, a vein does not traverse the stratum immediately above it, or is cut off in direction by a band of rock which it nowhere penetrates; or, again, if a given rock contains fragments of a neighbouring vein, it becomes evident that the vein may in each case be regarded as being older than the rock.

In this way it can often be shown that a vein must be older than certain formations in its neighbourhood, although it will generally be more difficult to determine how much older the vein may be than the evidently more recent rock. Such a determination can only be accomplished when the filling of a vein fissure may be referred to a period which elapsed between the formation of the rock which it traverses and that of a later deposit of well ascertained age, following closely in geological succession. Metalliferous veins are, as a rule, of more frequent occurrence in the older rocks than in the more recent ones, and from this circumstance it might possibly be inferred that the formation of lodes is a process which has gradually decreased in activity with the progress of time. It, however, appears far more probable that the formation of lodes has taken place at all periods of the world's history, and that, as a consequence, they are more frequently enclosed in the older rocks than in the newer ones; which, from being of less age, have been subjected during a less extended period to vein-producing influences. The following may be quoted as examples of mineral veins of comparatively recent date. In the department of Aveyron, in France, lodes of argentiferous galena associated with ores of copper traverse the Lias. In Algieria, lodes of the same class are enclosed in rocks belonging to the Cretaceous period. In California, a proportion of the auriferous veins are included in rocks of Jurassic age, while the auriferous quartz veins of Vöröspatak, in Transylvania, traverse Tertiary sandstones.

Further evidence that quartz veins are sometimes of very recent origin is afforded by the fact that in the vicinity of Volcano, in Amador County, California, a distinctly marked quartz vein is observed to cut through beds of sand and gravel, and presents unmistakable evidence of having been formed subsequently to their deposition, by the action of water holding silica in solution. This vein is chiefly composed of chalcedony and agate, but portions of it are more or less stained by a ferruginous deposit. This is by no means a solitary case, many other localities having been noticed where quartz veins, almost identical in their general features with those met with in the auriferous slates, must have been formed during the most recent geological epochs.[1]

From certain phenomena which have been observed in California, it would appear probable that in various localities lodes and other metalliferous deposits may, even at the present time, be in active progress of formation.

One of the largest deposits of sulphur in California occurs in Lake County, a mile beyond the ridge which bounds Borax Lake on its north-eastern side, and is many acres in extent. This "Sulphur Bank" is composed of a much decomposed volcanic rock, traversed by numerous fissures, from which gases, steam, and water, either in the form of spray or of vapour, constantly issue; and throughout the entire mass sulphur has been deposited in such large quantities that, at a short distance, the whole appears to consist of that substance. In the immediate neighbourhood of this solfatara are springs which give off carbonic acid, and of which

[1] *Geological Survey of California*, vol. i. 1865, p. 276.

the waters contain carbonates of sodium and ammonium, chloride of sodium, borax, &c.

The sulphur from this locality contains a small amount of mercury in the form of cinnabar, and the sides of the fissures in the volcanic rocks through which the gases and water make their escape are sometimes coated with gelatinous silica, beneath which is a layer of chalcedony resting upon a stratum of crystalline quartz. This siliceous deposit contains pyrites and a notable percentage of cinnabar, or is stained by a tarry hydrocarbon; while the crystals of quartz enclose liquid cavities in which the usual bubbles are distinctly visible.

In the year 1866 I visited Borax Lake and the neighbouring Sulphur Bank in company with Mr. R. Oxland, who was the first to call attention to the presence of cinnabar in the sulphur from this locality; and in 1868 I published a paper calling attention to the probability of certain mineral deposits having been the result of hydrothermal or solfataric action.[1]

For some years this solfatara was worked as a source of sulphur only; but during these operations so large an amount of cinnabar was discovered, both in the decomposed basaltic rock and in the sedimentary strata beneath it, as ultimately to lead to the opening up of the Sulphur Bank as a mercury mine. This has yielded large quantities of quicksilver, and affords a striking and instructive example of a recently formed mineral deposit resulting from agencies apparently still in operation.

Many years ago, silver was found in the sinter-like deposit from a hot spring in the county of Colusa; and, previous to 1865, Professor Whitney had been shown at Clear Lake some peculiar and interesting specimens of water-worn cinnabar enclosing specks of gold, said to have been found near Sulphur Springs in the same county.[2]

These, from being water-worn, and from not having been found *in situ*, necessarily lost a certain portion of the interest which would have otherwise been attached to them. Mr. Melville Attwood, of Saucelito, has however furnished me with a specimen of cinnabar from Colusa County, which, after having been formed upon one of the surfaces of a fissure, had subsequently become covered by a brilliant deposit of metallic gold.

Steamboat Springs, in the State of Nevada, are situated near

[1] "Notes on the Chemical Geology of the Gold-fields of California," *Phil. Mag.*, vol. xxxvi. 1868, p. 321.

[2] *Geological Survey of California*, vol. i. 1865, p. 92.

the base of a volcanic hill seven miles, in a direct line, north-west of Virginia City and of the famous silver mines on the Great Comstock Lode. The rock at this place is traversed by several parallel fissures, which either give issue to heated waters or simply throw off clouds of steam. The most active group of these crevices comprehends five parallel longitudinal openings extending, nearly in a straight line, for a distance of about a thousand yards; their general direction is nearly north-east and south-west, and all of them are included within a zone two hundred yards in width. They are sometimes filled with boiling water which overflows in the form of a rivulet, while at other times violent ebullition is heard to be taking place at a short distance below the surface.

These fissures are lined with a siliceous incrustation, which is being constantly deposited, while a central longitudinal opening allows of the escape of gases, steam, and boiling water. The water is slightly alkaline, and contains carbonate of sodium, sulphate of sodium, common salt, &c. Carbonic acid escapes nearly along the whole line, while sulphuretted hydrogen is evolved and a small quantity of sulphur deposited at certain points. The fissures, which appear to have been subjected to a series of repeated widenings, such as would result from an unequal movement of their walls, are lined, sometimes to a thickness of several feet, by incrustations of silica of various degrees of hydration, containing hydrated ferric oxide and, exceptionally, crystals of iron pyrites. This silica exhibits the ribbon-like structure so frequently observed in mineral veins, and, when examined under the microscope, is seen to consist of alternately amorphous and crystalline bands, enclosing druses lined with minute crystals of quartz.

At a distance of nearly a mile, in a westerly direction, from the locality above described is an older group of fissures in every respect similar to those of Steamboat Springs, except that they are no longer traversed by hot water, although still at various points giving off a little steam and carbonic acid. Towards the southern extremity of the principal fissure of this group the siliceous deposit extends considerably beyond the edges of the cleft, and has accumulated to a distance of many yards on each side of the opening. The silica of this deposit is sometimes chalcedonic and contains nodules of hyalite; the larger proportion of it, however, although somewhat friable, is distinctly crystalline. The crystals contain numerous liquid cavities, and exhibit the usual optical and other characteristics of ordinary quartz. Besides oxides of iron and manganese, this quartz contains small quantities of iron and copper pyrites; and in a paper on the Gold Regions of California, published in 1863, M. Laur states that he had found it to contain distinct traces of gold. With regard to these deposits, this gentleman remarks that, so far as auriferous quartz veins are concerned, Steamboat Springs appear to place before us a sort of practical verification of the theory which regards a certain class of metalliferous deposits as being produced by mineral waters in the fissures through which they circulate.[1]

For a long time local attention does not appear to have been directed to the Steamboat Valley; but in the year 1878 one of the older fissures was opened by a tunnel to a depth of fifty feet from the surface, and the veinstone was there found so impregnated with cinnabar as to yield a mercurial ore of some commercial value. At this depth the temperature was not sufficiently high to cause inconvenience to the workmen, and five samples of the ore which were subjected to assay gave an average yield of 2·90 per cent. of mercury. Steamboat Springs thus afford another example of the recent formation of a metalliferous deposit by the agency of heated waters.

In continuation of this subject it may be mentioned that a deposit of bright-red cinnabar in a brecciated vein mass occurs near the hot springs at Calistoga, at the foot of Mount St. Helena. Here fragments of an amorphous siliceous rock are cemented together by crystallized quartz showing distinct lines of accretion, throughout which minute granules of sulphide of mercury are plentifully disseminated.

The Great Comstock Lode is situated in a volcanic district seven miles south-east of Steamboat Springs, has a nearly similar orientation, and is enclosed between walls either of diabase, or of diorite on one side and diabase on the other. This vein, of which the gangue is chiefly siliceous, although calcite is also sometimes present, was first attacked by the miner in the year 1859, and since that time has yielded fabulous amounts of silver and gold.

The temperature of the waters issuing from mines worked upon the Comstock Lode has always been high, but it was not until they had attained a considerable depth below the surface that the workmen first became inconvenienced by extraordinary heat. At their present greatest depth (above 3,000 feet) water issues from the rock at a temperature of 157° Fahr. (70° C.); and, according to

[1] *Annales des Mines*, vol. iii. 1863, p. 423.

Mr. John A. Church, who has published valuable observations on the heat of the Comstock Mines, at least 4,200,000 tons of water are annually pumped from the workings at a minimum temperature of 135° Fahr.[1] He also estimates that to elevate such a large volume of water from the mean temperature of the atmosphere to that which it attains in the mines, would require 47,700 tons of coal. In addition to this, however, 7,859 tons of coal would, he calculates, be required to supply the heat absorbed by the air which passes along the various shafts and galleries through which it is diverted for the purposes of ventilation. It follows, therefore, that to develop the total amount of heat necessary to raise the water and air circulating in these mines from the mean temperature of the atmosphere to that which they respectively attain, 55,560 tons of coal, or 97,700 cords of firewood, would be annually required.

Mr. Church, in his paper, quotes four different analyses of waters from the Comstock Lode taken at different depths. These, as might have been anticipated, vary somewhat as to the relative proportions of the various substances present; but they contain on an average 42·62 grains of solid matter to the gallon. Of this amount, 20·74 grains are sulphate of calcium, 12·13 grains carbonate of potassium, 4·85 grains carbonate of sodium, and ·66 grain of chloride of sodium. In order to ascertain, approximately, to what extent the production of the large amount of heat absorbed by the water may be ascribed to oxidation of sulphur and iron, Mr. Church first calculates the quantity which would be developed by the oxidation of pyrites equivalent to the calcic sulphate in solution. Having found that this amounts to only $\frac{1}{143}$ part of that required, he subsequently seeks another solution for the difficulty, and, without bringing forward any calculations in support of the hypothesis, attributes this enormous development of heat to the kaolinization of felspar in the adjacent rocks.

This view, however new and ingenious, is unfortunately purely speculative, and in the present state of our knowledge geologists, generally, will regard this phenomenon as a last trace of volcanic activity. Mr. Church adduces the high temperature of the waters of Steamboat Springs as a proof that the rocks of this region are capable, by the kaolinization of felspar, of producing sufficient heat to raise large quantities of water to the boiling-point; but

[1] "The Heat of the Comstock Mines," *Trans. Amer. Institute of Mining Engineers*, vol. vii. 1879, p. 45. "The Comstock Lode; its Formation and History," New York, 1879. p. 189.

these springs give rise to an evolution of sulphuretted hydrogen, and, occasionally, to a deposition of sulphur, which cannot be results of the decomposition of felspar. It is probable that the Comstock Lode and the hot springs in the Steamboat Valley have had a somewhat similar origin, but, in the case of the former, volcanic agencies are no longer so actively in operation, while both sulphur and sinter, if originally present, have been removed by denudation. There can be no doubt that fissures and cavities have sometimes been filled by infiltration from the enclosing rocks, as well as by the percolation from the surface. The operation of these agencies is perhaps, in most instances, extremely slow, although according to R. Brough Smyth, even gold, under certain conditions, may be deposited in appreciable quantities within comparatively short periods. This author states that, in the gold-fields of Victoria, pieces of highly mineralized fossil wood, taken from the deeper workings, as well as timber used for supporting galleries, which had remained in the mine for some years, have exhibited, under the microscope, particles of gold adhering to and intermixed with crystals of iron pyrites, all through the central parts of the wood.[1] This is confirmed by Mr. Ulrich, who says that in the gold-drifts pyrites is often found incrusting or replacing roots and driftwood, and that samples, assayed by Messrs. Daintree, Latta, and Newberry, have yielded amounts of gold varying from a few pennyweights to several ounces per ton. According to Mr. H. A. Thompson, a specimen of pyrites from the centre of an old tree-trunk gave by assay above 30 oz. of gold per ton.[2]

Genesis of Mineral Veins.—The origin of metalliferous veins is a subject which has long occupied the attention of geologists, and various theories have, at different times, been framed with the object of explaining the causes which have led to their formation.

Little is said upon this subject by Greek and Latin authors when referring to mines and minerals. Diodorus Siculus, however, who lived and wrote during the first years of the Christian era, states that the mountains of Spain are traversed by metalliferous veins.

Pliny, whose death is supposed to have taken place A.D. 79, tells us in the thirty-third Book of his Natural History that gold is found in mountainous districts, and that veins producing it traverse the rocks in different directions, and often appear in the walls or sides of wells. He further informs us that if a lead vein be

[1] "The Gold-fields and Mineral Districts of Victoria," Melbourne, 1869, p. 74.
[2] Alfred R. C. Selwyn and George H. F. Ulrich, "Notes on the Physical Geography, Geology, and Mineralogy of Victoria," Melbourne, 1866, p. 56.

allowed to remain for some time unworked, air being at the same time freely admitted into the mine, a fresh growth of lead ore will take place and the lode will become even richer than before.

Werner, in his *New Theory of the Origin of Veins*, has given a concise history of the older views on this subject, of which a brief summary may not be without interest.[1]

Georgius Agricola, whose real name was Bauer, and who was born in 1494 at Glauchau in the Saxon Erzgebirge, treats of the position and crossing of lodes in the twenty-fourth chapter of his *Bermannus*, and at still greater length in his great work *De Re Metallica* (1556). In the third chapter of the third book of his work *De Ortu et Causis Subterraneorum* (1546), Agricola treats of the formation of veins. He supposes the fissures in which they are found to have been formed partly at the same time as the enclosing rocks, and partly afterwards by the waters which penetrated into them. With respect to the clays and stones constituting portions of metalliferous veins, he conceives the former to have resulted from the abrasion of neighbouring rocks, and to have been carried into the vein fissures by water; the latter he regards as resulting from the clayey or earthy matters which have become hardened partly by the effects of heat and cold, and partly by a "lapidific juice." Minerals and metals he regards as being deposited from solution in water, and he considers the then prevalent belief that lodes are of the same age as the globe itself "an opinion of the vulgar."

Rössler, who died in 1673, also regarded veins as fissures previously existing in the rock and subsequently filled with minerals.[2]

Becher (1669) ascribes the formation of metals and minerals to subterranean vapours penetrating the veins and producing a peculiar change in their earthy and stony constituents.[3]

Henckel (1725) attributes the formation of the contents of veins to a peculiar exhalation produced and engendered by a "fermentation" supposed to take place in the interior of rocks.[4]

Hoffman (1738) supposes lodes to have been formed in the fissures of rocks, but speaks of this as being an hypothesis only.[5]

[1] A. G. Werner, "Neue Theorie von der Entstehung der Gänge," Freiberg, 1791. An English translation of this book by Charles Anderson, M.D., was published at Edinburgh in 1809.

[2] B. Rössler, "Speculum metallurgiæ politissimum, oder hellpolierter Bergbauspiegel," Dresden, 1700.

[3] J. J. Becher, "Physica Subterranea," Frankfurt, 1669.

[4] J. F. Henckel, "Pyritologia oder Kieshistorie," Leipzig, 1725. An English translation of this work was published in London in 1757.

[5] J. G. Hoffman, "De Matricibus Metallorum," Leipzig, 1738.

Zimmerman (1746) considers veins and the minerals of which they are composed, to have been produced by a transformation of the substance of the enclosing rocks; this alteration being assisted by certain saline substances which prepare and render the earthy matters capable of being changed into metalliferous minerals and their accompanying veinstones.[1]

Von Oppel (1749), formerly Captain-General of the mines of Saxony, admits without reservation that veins were formerly fissures in the rock which were afterwards filled with mineral substances of a different nature from the surrounding rock.[2]

Lehmann (1753) is of opinion that veins are fissures which have been filled by nature with stones, minerals, metals, and clay, and that they appear to be the branches and shoots of an immense trunk placed at a prodigious depth in the bowels of the earth. From this central workshop where nature carries on the manufacture of the metals, the metalliferous constituents of lodes have issued in the form of "vapours and exhalations."[3]

Delius (1770) considers vein fissures to be rents, which have been since filled up, caused by the drying of the rocks. He is, moreover, of opinion that rain, having penetrated the substance of the country rocks, has dissolved or suspended, and afterwards carried into the rents, the different materials which have served as a base for the formation of the gangue and various associated ores.[4]

Baumer (1779) states that veins differ both in form and substance from the strata in which they occur. Their formation he considers to be posterior to that of the rock traversed by them, and they appear to have been formed under the sea, as they are often covered by beds of schist, and marine animals are sometimes found in them in a fossil state.[5]

Gerhard (1781) believes vein fissures to have been produced at very different periods of time, and is disposed to think that "subterraneous fermentations" may have contributed to their formation. He supposes further that water penetrating the country rock dissolves certain substances, and afterwards passing into vein fissures, there deposits the minerals which it previously held in solution. These minerals, he is of opinion, existed originally in the adjacent rocks, and have been carried in a state of aqueous solution into the

[1] C. F. Zimmerman, "Ober-Sächsische Bergakademie," Dresden, 1746.
[2] v. Oppel, "Anleitung zur Markscheidekunst," Dresden, 1749.
[3] J. G. Lehmann, "Abhandlung von den Metallmüttern," Berlin, 1753.
[4] C. T. Delius, "Abhandlung von den Ursprünge der Gebirge," Leipzig, 1770.
[5] J. G. Baumer, "Fundamenta Geographiæ et Hydrographiæ subterraneæ," Gotha, 1779.

fissures, where they are now found in the form of metalliferous veins.[1]

Von Trebra (1785) does not appear to have possessed any very definite ideas on the subject of metalliferous veins, but ascribes their origin mainly to the action of "putrefaction and fermentation." He appears to regard the two terms as synonymous, and subsequently defines the latter as "the quality which, acting by insensible degrees, produces the most perfect transformation in the bowels of the earth."[2]

Lasius (1789) considers veins to have been formed in rents produced by revolutions of nature, and these he believes to have been afterwards filled with water containing carbonic acid, which thus acquired the property of dissolving various earthy and metallic matters contained in the rocks through which they percolated. These substances were afterwards precipated by certain other bodies in the fissures in which they are now found. He, however, is not clear as to whether the metallic particles were already present in the substance of the rock, or were formed in them by the action of water upon minute "metallic seeds."[3]

Werner (1791), in his work on the formation of veins, propounds at considerable length his views upon this subject, and of these the following may be regarded as being a brief abstract. All true veins were originally open rents, which were afterwards filled with mineral matter from above.

Rents or fissures may have been produced by various causes. Mountains have been formed by a successive accumulation of different beds upon one another; the resulting mass was at first wet and possessed little solidity or coherence, so that when the accumulation had attained a certain height it yielded to its weight, sank, and cracked. In proportion as the waters which had previously assisted to support such an accumulation had partially retired, the masses, losing their previous support, yielded to the action of gravitation, and portions of the mountain thus became detached, falling to the "free side," where the least resistance was opposed. The cracking of a mountain mass by desiccation, by earthquakes, or by other similar causes, may also have contributed to the formation of rents of this character.

The same precipitation which in the humid way formed the strata and beds of the rock, also furnished the substance of mineral

[1] C. A. Gerhard, "Geschichte des Mineral-Reichs," Berlin, 1781.
[2] F. W. H. v. Trebra, "Erfahrungen von Innern der Gebirge," Dessau, 1785.
[3] G. O. S. Lasius, "Beobachtungen über die Harzgebirge," Hanover, 1789.

veins. This took place during the period the solution from which the precipitate was deposited, covered the already existing fissures the upper portions of which were, as yet, open, and wholly or in part empty.

The various theories which have at different times been brought forward to account for the formation of metalliferous veins, admit of being classified as follows:—

1. Theory of Contemporaneous Formation.
2. " Igneous Injection.
3. " Electric Currents.
4. " Aqueous Deposition from above.
5. " Sublimation.
6. " Lateral Secretion.
7. " Ascension.

1. *Theory of Contemporaneous Formation.*—This theory supposes that mineral veins originated contemporaneously with the enclosing rock, and they are regarded as mere accidental phenomena governed by no fixed laws of formation. This hypothesis is at variance with all known facts relating to the subject, and may consequently be dismissed without further consideration.

2. *Theory of Igneous Injection.*—According to this theory, which is generally adopted with regard to dykes of igneous rocks, the constituents of metalliferous veins, under the influence of intense heat and pressure, and when in a more or less fluid state, have been ejected from below into cracks and fissures in the superincumbent strata. Examples of the occurrence of metalliferous matter disseminated through eruptive rocks are by no means uncommon, but this theory entirely fails to account for many of the commonest and most characteristic phenomena which are observed in connection with mineral veins. The comby structure of lodes, and the changes which occur in their character when they pass from one series of rocks into another, are not only quite incapable of explanation by this theory; but, moreover, had veins been generally thus formed, a tendency would probably have been manifested by the heavier ores and metals to arrange themselves in the lowest portions of the lodes in which they occur.

The veins of Lake Superior, which annually yield such large quantities of native copper, have been cited as affording examples of veins produced by igneous ejection; but metallic copper is there found associated with chemically pure silver, whereas, had the veins been the result of igneous fusion, an alloy of the two metals would certainly have been formed.[1] In the same region crystals of chemically pure silver deposited on the surface of masses of native copper are by no means of unfrequent occurrence. In these lodes, moreover, native copper is found enclosed in crystals of calcite and in other minerals, where it must evidently have been deposited, with the other constituents of the crystalline mass, from aqueous solution.

There is, however, distinct evidence that many igneous rocks contain, disseminated through them, minute quantities of various compounds of the heavy metals, and that in some cases these have been dissolved out and the metals again thrown down in such a way as to form valuable metalliferous deposits. The so-called *mullock veins* of Australia and elsewhere are examples of eruptive dykes which, having become decomposed, the originally disseminated gold and silver have, with quartz and other minerals, been deposited in the joints and fissures of the rock.

Although unaltered dykes of this kind are not often sufficiently rich to be classed with metalliferous deposits, it is by no means improbable that richer intrusions may exceptionally occur, and that some of the so-called eruptive lodes at Schemnitz and other localities may directly owe their origin to eruptive agencies.

3. *Theory of Electric Currents.*—Mr. R. W. Fox after having ascertained the existence of electric currents in many of the metalliferous veins of Cornwall, suggested the probability of this force having acted on various metallic chlorides and sulphides dissolved in the waters traversing vein fissures, in such a way as to determine the mode of the distribution of the ores therein. He also endeavoured to account for the prevalence of an easterly and westerly direction in the principal lodes of Cornwall by their position in relation to the earth's magnetism.

Weighty objections to this theory have, however, been pointed out by W. J. Henwood and others, and observed facts appear to indicate that the general direction of veins differs so entirely in different mining districts that their course probably depends rather on lines of fracture, produced by plutonic, volcanic, or other agencies, than on the action of electric currents. Professor Reich, who repeated the experiments of Fox, also obtained a deflection of the magnetic needle when he connected two portions of the same lode by means of conducting wires. He, however, very clearly explains this as the effect of the contact of various ores composing

[1] J. S. Newberry, "The Origin and Classification of Ore Deposits," *School of Mines Quarterly*, March, 1880, New York.

isolated bunches, separated by sterile veinstone which acts as a moist conductor. By connecting points free from ore, Reich was unable to obtain the slightest deviation of the needle, and, although the chemical changes which are continually taking place in exposed masses of ore give rise to electric currents, it by no means follows that the original distribution of the same ore was due to the agency of electricity.

4. *Theory of Aqueous Deposition from above.*—This was first advanced by Werner, who supposes the contents of mineral veins to have been deposited from metalliferous solutions which flowed from above into the fissures. If, however, fluids containing metalliferous substances at any period actually covered the surface, there would appear to be no reason why they should have deposited their contents in fissures rather than elsewhere. Besides which, if the deposition of vein matter took place in the way supposed, we might expect to find at least some portion of the veinstone stratified horizontally, which in true veins is never seen to be the case. Many conclusive reasons against the ideas promulgated by Werner might, if necessary, be brought forward, but his views with regard to the origin of veins have long ceased to carry the weight once attached to them, and are now very generally abandoned.

Mr. Wallace, in his work on *The Laws which Regulate the Deposition of Lead Ore in Veins,*[1] which laws, although having special reference to the Alston Moor district, are advanced by him as explaining ore deposits in veins generally, appears to adopt to some extent the views of Werner with certain additions and modifications. He states that all the lead veins of that part of England are most productive where furthest removed from seats of plutonic action, the richest deposits being in the upper part of the Carboniferous Limestone where no igneous rocks are found, and that there is nothing in that district to support the theory that lead ore is due either to exhalations from below or to matter injected in a fluid state among the consolidated sedimentary rocks. On the contrary, he thinks a more probable cause of the deposits of lead ore in Alston Moor may be traced to segregations resulting from the decomposition of the wall rocks of the veins in which lead ore is found.

In adopting the doctrine of segregation, he proposes to combine it with another cause without which there would, he believes, be

[1] W. Wallace, "The Laws which Regulate the Deposition of Lead Ore in Veins; Illustrated by the Mining Districts of Alston Moor," London, 1861.

no important deposit of minerals, namely, that of recent atmospheric agencies. Without the passage of large bodies of water, derived from the rainfall of the district, from the surface downwards, and their free circulation in the veins, he maintains that the conditions would not be favourable to the deposit of minerals. He states also that in all cases such deposits are found only where fluids percolate freely from the surface and circulate through the veins, and that such conditions only occur in strata situated at moderate depths, and at a considerable distance from the surface watershed. He believes these agents, combined with electrical action, to have been the means of extracting the minerals from the neighbouring rocks, that this operation is still in progress, and that the filling of vein fissures has been entirely accomplished since the Glacial period.

The theory of aqueous deposition from above has still more recently been advocated by Professor Stewart of Nevada, but Mr. J. S. Newberry who has devoted a long time to the study of the ore deposits of the Western States of America, considers that this theory is not only not sustained, but, on the contrary, is disproved, by the statements brought forward.

5. *Theory of Sublimation.*—According to the theory of sublimation, vein fissures were filled by the volatilization of metalliferous minerals derived from the ignited interior of the globe. Durocher[1] considers the unequal distribution of the ores in all lodes as strongly confirmatory of the hypothesis of their formation by this agency. He believes that ores can only have been so distributed by the action of currents of dissimilar gases or vapours circulating through the fissures in the veinstone. Of these he distinguishes two kinds, namely, metallic vapours, *émanations motrices*, and vapours of sulphur and other mineralizers, which he designates *émanations fixatrices.* These, when they circulate through different fissures without meeting, or through the same fissures at different periods, produce no result, but, when they meet together, give rise to various metalliferous deposits. Numerous experimenters have shown the possibility of producing by such means many of the ores which occur in metalliferous veins and deposits of magnetite and specular iron ore produced by the decomposition of chlorides of iron by watery vapour in the fissures of volcanic rocks, afford well-known examples of the natural production of minerals by reactions of this class.

Plattner long ago observed the formation, by sublimation, of

[1] *Comptes rendus de l'Académie des Sciences*, vol. xxviii. 1849, p. 607.

magnetite and galena in the Freiberg furnaces, and Daubrée[1] has succeeded by the aid of chlorine, fluorine, &c., in producing by sublimation tin oxide and oxide of titanium. Similar results were obtained by Durocher, who passed metallic vapours, &c., through heated glass tubes, and thus caused the formation of blende, pyrites, galena, and other various metallic sulphides.[2] Evidence in favour of the theory of sublimation has, by some geologists, been supposed to be furnished by the position of metalliferous particles found on the under sides of crystals lining the walls of certain lodes, as at Nagýag, in Transylvania, where metallic arsenic has been deposited on the lower faces only of crystals of diallogite.

Such phenomena are, however, of comparatively rare occurrence, and will in no way account for the existence of the earthy minerals which constitute the larger proportion of the filling of nearly all large veins. It is impossible also to account by this means, either for the variations which take place in the character of lodes on passing from one rock into another, or for many of the complicated phenomena exhibited by veins at their intersections with one another.

In the case of some irregular deposits where large masses have become impregnated by a metalliferous mineral, as especially exemplified in certain mercury mines, it is perhaps not improbable that the diffusion of the ore may have been partially effected by sublimation. The deposition of cinnabar, iron pyrites, and even gold, from the mingled steam and water of some of the geysers of California would indicate the possibility of such impregnations taking place, but, in the present state of our knowledge of the subject, it would appear improbable that the silica which usually forms so large a proportion of veinstones, and frequently occurs in combs of interlocking crystals, should have been deposited otherwise than from aqueous solution. It is therefore probable that, although sublimation may sometimes have contributed to the impregnation of rocks by cinnabar and other minerals, its action must have been of secondary importance in the formation of regular metalliferous veins.

6. *Theory of Lateral Secretion.*—This theory teaches that water percolating through the country rock has, by the aid of carbonic acid and other natural solvents, dissolved out of it all the materials now forming the constituents of mineral veins. Delius, Gerhard, and Lasius held that this explanation was that most in accordance

[1] *Comp. rend.*, vol. xxix. 1849, p. 227.
[2] *Comp. rend.*, vol. xxxii. 1851, p. 823; vol. xlii. 1856, p. 850.

with observed facts, and more recently Bischof endeavoured to found this hypothesis upon more scientific grounds. He, however, appears to have failed to seek for the constituents of the different ores, found in veins, in the surrounding rocks, but suggests the possibility of their being found there if sought for, at the same time remarking that the proof of this was nevertheless wanting.

About the year 1873, Professor Sandberger, of the University of Würzburg, began to direct his attention to a chemical examination of the relations existing between the mineralogical contents of mineral veins and the nature of the rocks which they traverse. Although some of the more common heavy metals had previously been discovered in various crystalline and other rocks, this was the first systematic attempt to study the effects produced upon veins by the country rock through which they pass. For the purpose of this investigation the north-eastern portion of the Black Forest in the neighbourhood of Schapbach, Wittichen-Reinerzau, and Wolfach, was selected, this being a district with which the Professor had been long and intimately acquainted. The lodes in this region, although situated at short distances only from one another, exhibit very remarkable differences, which are most strongly marked on their passing from one description of rock into another; the same change, although in a less degree, however, is also noticeable on the passage of a lode from one variety of gneiss into another somewhat differing from it in character.

Quantitative analyses were carefully made of ores, veinstones, and country rocks, the latter being subjected to general analysis. These investigations resulted in the derivation of the veinstones from the country rock being clearly established, but the origin of the associated metalliferous minerals still remained without explanation. As, however, it became more and more evident that substances so constantly associated as ores and veinstones must have had a common origin, a new method of investigation was finally adopted. Instead of operating upon a large quantity of rock, and making a general analysis of it, as had been done by Forchhammer, the crystallized constituent silicates, such as olivine, augite, hornblende, and mica, were carefully isolated and subjected to analysis, the quantity treated in each case being not less than ten grammes. In this way, with the exception of tellurium, gold, and mercury, which from want of the necessary appliances were not sought for, all the elements usually occurring in metalliferous veins were found in appreciable quantities.

The cause of the differences which occur in the contents of veins, which although near one another traverse different rocks, was also explained to the satisfaction of the investigator, who subsequently satisfied himself that the heavy metals occur in the silicates of crystalline rocks of every geological age.[1]

Sandberger has since extended his investigations over very considerable areas, and has thus been enabled to arrive at certain general and very important conclusions. In the case of olivine, augite, hornblende, or mica, from ten to twenty grammes will be found a sufficient amount for quantitative analysis. In olivine, iron, nickel, copper, and cobalt were constantly recognized, but the latter metal in very small quantities. The same may be said with regard to augites, especially those of the gabbros, diabases, melaphyres, augite-porphyries, augite-andesites, and basalts. Copper, cobalt, and iron occur in the augite of these rocks in notable quantities, and nickel, lead, tin, and zinc are also frequently present. Antimony and arsenic have hitherto been detected in certain localities only, but when present these metals are generally found in considerable quantity, as, for example, in the diabases of St. Andreasberg in the Harz, in which antimony is associated with lead. Hornblende from the older hornblendic rocks constantly contains copper, arsenic, and cobalt, and along with these very distinct indications of nickel. Hornblende from the more recent rocks contains the same metals, but in addition to them lead, antimony, and tin, with occasionally zinc and bismuth.

The largest number of hitherto undetected heavy metals is, however, found in micas, the researches on this group having been carried so far that they may now, to some extent, be classified in accordance with the preponderance of certain metallic elements. All lithia micas, even when derived from the most varied localities both in Europe and America, are stanniferous, and they usually also contain arsenic, copper, bismuth, and sometimes uranium. True muscovites are the micas poorest in heavy metals, although copper is seldom entirely absent. The black micas from the older gneiss of the Erzgebirge, contain arsenic, lead, zinc, and a little copper, and the same applies to those of the southern Black Forest, while the black mica from the Spessart contains copper, cobalt, nickel, and bismuth. Arsenic, lead, and zinc are found in the dark

[1] Fridolin Sandberger, "Untersuchungen über Erzgänge," Part I. p. 23.

mica from the propylite of Schemnitz, and in the rubellan of Pölma, near the boundary of Saxony and Bohemia.

Attention is called by Sandberger to the fact that both baryta and lime are present in various felspars as well as in the minerals with which they are associated, and that fluorine occurs in many micas. The decomposition of such minerals will therefore yield the materials for the formation of many varieties of veinstone, while the liberated silica will be deposited in the form of quartz.

Organic matter is sometimes present in considerable quantities in metalliferous veins, not only in the form of carbonic acid, but also as graphite and anthracite, as at Schneeberg and elsewhere. It also occurs as the colouring matter of fluor spar and of smoky quartz. This, it is argued by the supporters of the theory of lateral secretion, will be found whenever the amount originally present has been more than sufficient to transform the metallic sulphates into sulphides, &c.

Lodes however occur not only in crystalline rocks, but also in semi-crystalline strata, &c., and according to this theory the ores of such veins may be derived from three sources, namely, from the incompletely decomposed remains of metalliferous silicates derived from the original crystalline rocks, from solution-products of older veins, and, finally, under special circumstances, from traces of the metals which are contained in sea water. The last source will probably have directly supplied only a limited number of deposits.

It has however been shown that the fresh mother-liquors from the salterns of the Mediterranean contain sufficient copper to be recognizable in 5 cc. of the liquid, at which rate one cubic metre of the water of that sea will contain at least 0·01 grm. of copper. The black and usually very sulphurous matter deposited in basins where sea water has been left to itself, constantly contains copper, and the same is generally true with regard to the dark-coloured gypseous muds of all ages. The copper schists of Mansfeld contain organic matter in considerable quantity, together with copper, and ammoniacal salts equivalent to 0·000816 grm. of ammonia per kilogr. of rock, easily recognizable in a few grms. Lithia is also present in sufficient amount to produce a very brilliant spectral line. These associations are exactly similar to those which occur in modern estuarine muds.[1]

According to recent analyses, the phyllites of the Erzgebirge and Fichtelgebirge are by no means rich in the heavy metals, but if a sufficient amount of the rock be operated upon their presence

[1] L. Dieulafait, *Revue universelle des Mines*, vol. vii. 1880, p. 425.

can always be detected. The dark-grey phyllite of Schneeberg contains arsenic, cobalt, and nickel; while the Cambrian schists of Goldkronach afford arsenic, antimony, and lead. The sericite schists of the Taunus yield from ·05 to ·06 per cent of cupric oxide.

Stratified rocks of purely neptunian origin, with the exception of limestones, consist chiefly of the débris, in a more or less finely-divided state, of older crystalline rocks. It is not to be expected that they will not have lost a portion of the heavy metals originally contained in the rocks from which they were derived, but some one or more of them may nevertheless be almost always detected. H. Frick [1] first detected the presence of oxide of copper in clay slates; and by operating upon 1 lb. of roofing slate from Bangor, North Wales, Forchhammer [2] obtained a large quantity of lead, in addition to copper and zinc.

Bischof, many years since, expressed the opinion that if properly looked after copper would be found in all clay slates, and subsequent investigation appears to go far in support of this view.[3] Sandberger discovered copper, zinc, lead, arsenic, antimony, tin, cobalt, and nickel in clay slates from the neighbourhood of Holzappel, as well as in those from Ems, and from Schulenberg, near Clausthal. Titanic and phosphoric acids also appear to be everywhere present in small quantities. Many rocks of New Red Sandstone age contain lead and copper. Lead, copper, arsenic, and cobalt occur, in Germany, in the clay slates of the lower Keuper. The bituminous, marly slates of Raibl, in Carinthia, are rich in lead and zinc; but these metals are only obtained after fusion with an alkali, showing that they are present in the form of silicates only.

These investigations which have resulted in demonstrating the almost universal presence of heavy metals in rocks belonging to every geological period, tend greatly to enlarge our views on the subject of metalliferous deposits. There can be no longer any doubt that the filling of veins has often been derived, in a state of chemical solution, from the surrounding country rock, and the theory of lateral secretion appears to explain more satisfactorily than any other, certain phenomena not otherwise easily understood. It, moreover, not only accounts in a satisfactory way for the changes which take place in metalliferous veins when passing from one formation into another, but it also affords a reasonable explanation for the fact that shoots of ore usually follow the dip of the enclosing rocks.

[1] *Poggend. Annal.*, vol. xxxv., 1835, p. 193. [2] *Ibid.*, vol. xcv. 1855, p. 70.
[3] G. Bischof, "Lehrbuch der chemischen und physikalischen Geologie," 1847, vol. ii. p. 1900. English Translation, vol. iii. 1859, p. 122.

It has been suggested by various geologists that certain strata, instead of being richer than others in metals, may possess a composition enabling them to act more efficiently in decomposing metalliferous solutions derived from other sources, and in depositing their contents in the form of ores. This reaction may perhaps sometimes influence the ore-bearing portions of a lode, but its importance may be regarded as secondary to the influence of the metalliferous contents of the rocks themselves.

Among the objections which have at various times been advanced against this theory may be mentioned the facts that different sets of fissures traversing the same formations often contain very different ores, and that when rocks of totally different character are brought by faulting to form opposite walls of a fissure, the ore may be, nevertheless, symmetrically deposited in corresponding layers. It may likewise be remarked that the same fissure frequently traverses several formations, and the character of the vein may throughout be essentially the same. It cannot however be doubted that the formation of lodes has been a long and complicated process, all the phenomena connected with which are not capable of explanation by any one cause. If the term *lateral secretion* be employed in a somewhat extended sense, and it be understood to imply that the solution, after becoming impregnated by the rocks, had free movement in the fissure, so that each molecule was not deposited where it issued in solution from the country, this theory passes directly into that of the ascension of aqueous solutions.

7. *Theory of Ascension.*—This theory supposes lodes to have been formed in part only of minerals dissolved out of rocks in the immediate horizon of their several deposits in vein fissures, and that the chief portion of the material has been derived from greater depths by solvents circulating through the fissures. According to some who have advocated this theory, sublimation, either with or without steam, has also assisted in the formation of metalliferous veins. The increased heat and pressure, due to great depth, will thus greatly facilitate the solution of the different vein-forming substances; and minerals may be deposited in all parts of the fissure of which the constituents do not exist in the rocks in its immediate vicinity. These solutions will, under a pressure due to the height of the column, penetrate more or less deeply into the surrounding rocks, and may, under certain circumstances, give rise to their impregnation by metalliferous minerals. By the same agency the adjacent rocks are sometimes softened and decomposed to a considerable distance from the lode; or the country rock may,

on the contrary, give rise to the formation of capels through becoming hardened by silicification. Waters, possessing solvent powers vastly increased by high temperature and great pressure, percolating through rocks containing the heavy metals will gradually remove them, by lixiviation, together with other mineral substances, and these will again be deposited upon the sides of the fissure in proportion as the solvent power of the menstruum becomes lessened by diminishing temperature and pressure. On the other hand, it is probable that minerals diffused in rocks comparatively near the surface may have been removed by solutions which, penetrating into vein fissures, have mingled with the waters circulating through them. With regard to the precise chemical reactions which take place in the deposition of ores in mineral veins we have yet much to learn, but there can be no doubt that deposits somewhat akin to those of true veins are at the present time being formed by the action of certain thermal springs.

In a paper before referred to Newberry strongly advocates the theory of aqueous ascension, and appears to believe that no other is capable of explaining all the various phenomena connected with the formation of lodes. After briefly adverting to other theories he remarks:—" But argument is really wasted in a discussion of the filling of fissure veins, since we have examples that seem to settle the question in favour of chemical precipitation from ascending hot water and steam. In the Steamboat Springs of Western Nevada, for example, we in fact catch mineral veins in the process of formation. These springs issue from extensive fissures which have been or are being filled with siliceous veinstone, that carries, according to M. Laur, oxide of iron, oxide of manganese, sulphide of iron, sulphide of copper, and metallic gold, and exhibits the banded structure so frequently observed in mineral veins."

To this theory Sandberger objects, on the ground that none of the numerous mineral springs which he has examined, namely, those of Petersthal, Rippoldsau, Baden, Badenweiler, the Maxquelle of Kissingen, and others, deposit any mineral incrustation on the walls of their channels of exit, although they subsequently, upon exposure to the air, give rise to muddy deposits containing various heavy metals. The Sulphur Springs in Colusa County, California, and Steamboat Springs in Western Nevada, he regards as exceptional phenomena only to be compared with the unimportant metalliferous deposits produced by solfataras or fumaroles, or which issue from fissures in heated lava. He further remarks that with the exception of California no country, either in the new or old world, possesses ore deposits containing such masses of free sulphur. According to the same author the various metallic sulphides which so constantly occur in lodes are the results of the reduction of sulphates by the action of organic matter.

It may, however, be stated, on the other side, that the rule relative to the non-deposit of minerals in channels giving issue to hot waters is not without remarkable exceptions, since at Steamboat Springs an adit was driven in such a way as to intersect, at a considerable depth from the surface, a fissure which once formed a vent for mineral waters. At that depth the banded structure was not only continued, but the veinstone, which consisted chiefly of quartz, contained a notable proportion of cinnabar.

Sulphur is by no means abundant in the deposits of Steamboat Springs, and is for long distances entirely absent. Native sulphur, however, occurs in the mineral veins of America, Australia, and some other countries. It has been found in the gold mines of Virginia and North Carolina, as well as in antimony reefs at Costerfield in Victoria, and in veins at Maldon, St. Arnaud, and Castlemaine in the same colony.

Sulphur is also of not unfrequent occurrence in the auriferous quartz reefs of Southern India, where, in the form of transparent crystals, it covers the surfaces of small druses in the veinstone. Specimens kindly forwarded to me by Mr. H. A. Severn from the Wynaad were in the form of octahedra, and had been deposited upon an extremely thin coating of ferric oxide lining a cavity, the length of the greater diameter of which was about one inch. It is evident that the presence of sulphuretted hydrogen may sometimes account for the formation of certain metallic sulphides, without the intervention of organic matter.

Concluding Observations.—It appears to be now well established that the heavy metals occurring in metalliferous veins in the form of ores are, in the state of silicates or of other mineralized combinations, present in greater or less proportions in rocks of almost every age, and that these are capable of supplying all the chemical constituents of the different ores and veinstones of the lodes passing through them.

That the minerals thus disseminated throughout the rocks have been originally the source of the metalliferous accumulations which have taken place in veins admits of little doubt, but we have still much to learn with regard to the processes by which ores of the different metals have become concentrated in fissures. In the majority of cases this must have been effected by chemical solution and subsequent deposition, as indicated by the comby structure of many lodes, as well as by the occurrence, one upon another, of such minerals as quartz, calcite, and ores of iron.

It is possible that, in some cases, waters to some extent charged with heavy metals may have flowed from above into fissures where a portion of them may have become deposited in the form of ores, as suggested by Mr. Wallace, but it does not appear probable that the flow of surface waters into vein fissures can, generally speaking, have materially contributed to the richness of mineral veins.

There is reason to believe that lodes may have often been produced by lateral secretion at ordinary temperatures, and that the ores and other minerals constituting veins may have been deposited in approximate vicinity to the points at which the solutions entered the fissure. As, however, the fissures of true veins are supposed to extend far into the earth, we are justified in believing that the solvent powers of the menstrua, acting upon minerals disseminated through the strata, will be increased by a high temperature and the pressure incident to great depth. These heated waters, obeying known laws, will have a tendency to ascend, and in doing so will gradually lose their power of holding minerals in solution, and a deposit on the surfaces of the fissures will be the result. Metalliferous veins are of more frequent occurrence in the neighbourhood of eruptive rocks than in other situations, and it is probable that these may have not only been instrumental in producing fissures, but may also have contributed to supply heat to the waters circulating through them.

Metallic minerals, especially specular iron ores, are sometimes deposited by sublimation in the crevices of cooling lavas, and it is probable that in certain solfataras, like that near Borax Lake, in California, the concentration of a portion of the cinnabar and other substances present may be partially due to this agency. Many bodies which are not easily volatilized are readily carried along by a current of steam or aqueous vapour. There is, apparently, no reason for believing that sublimation has usually acted an important part in the formation of true veins, notwithstanding the fact that free sulphur sometimes occurs in metalliferous veins.

b. SEGREGATED VEINS.—Metalliferous deposits belonging to this class differ from true veins inasmuch as they are conformable with the bedding or foliation of the country rock, whereas true veins traverse all formations independently of stratification and foliation. As in the case of ordinary lodes the gangue of segregated or *bedded veins* differs entirely from the surrounding rock, the veinstone, which frequently consists of quartz, being often crystalline and exhibiting a distinctly banded structure. Besides extending uninterruptedly for considerable distances, deposits of this class sometimes form lenticular masses of limited extent; these are, however, often followed by others of a similar description forming a series resembling a more or less interrupted lode. The quartz veins so numerous in Canada, New England, and in the Alleghany Mountains are generally examples of deposits of this class, as are, for the most part, the auriferous veins of California. Fig. 34 represents an ideal section of this form of deposit. The ore-bearing mass does not always crop out at the surface, although it frequently does so; *a* is a vein which makes its appearance at the surface, *b* does not reach so far; while *c* is a lenticular bunch extending but a short distance either upwards or

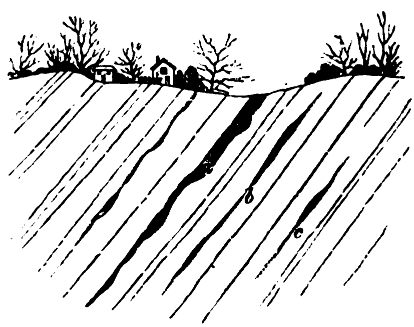

FIG. 34.—Segregated veins.

downwards. One of the most important constituents of segregated veins is gold, with which either pyrites, blende, galena, or chalcopyrite is almost always, to some extent, associated. In common with true veins, segregated veins frequently exhibit evidence of repeated openings of the fissure, and of fresh depositions of mineral. It was formerly believed that veins of this description are less persistent than true lodes, that they are richer nearer the surface than elsewhere, and that they frequently terminate by pinching out both in depth and in horizontal extension. Recent mining operations have, however, materially modified the received views respecting the value and persistency of the so-called segregated veins. Many of them are of great thickness and extent, and after having been worked to very considerable depths, have been there found as productive as they were nearer the surface. The character of the veinstone of such deposits frequently appears to in no way vary from that of true fissure veins, from which they often differ in no respect except that their course is parallel to that of the strata between which they lie. It therefore becomes a question whether segregated deposits and true veins have

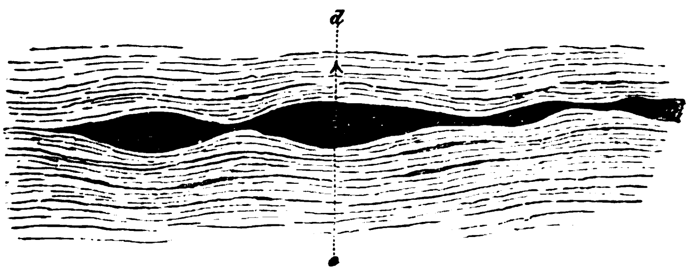

FIG. 35.—Lenticular segregations; plan.

not often a common origin, and whether in thus naming them differently we are not sometimes making a distinction where no difference, beyond the parallelism or non-parallelism of the deposit with the enclosing strata, exists.

Deposits of auriferous quartz, cupriferous iron pyrites and some other minerals, occasionally assume the form of a series of lenticular

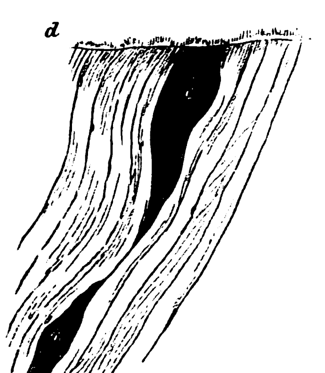

FIG. 36.—Lenticular segregations; section on *d e*.

masses, which lying between the foliations of the strata, follow one another both in length and depth in such a way as to constitute an interrupted vein. Fig. 35 represents in plan, and Fig. 36 in section on the line *d e*, a deposit of this kind, in which *a* indicates masses of either veinstone or ore. Such lenticular masses, which are often approximately continuous and lie at low angles, are described as beds, *Lager*, by v. Groddeck. They, however, occasionally enclose fragments of the country rock both from the foot and hanging walls, and, in such cases, cannot be regarded as contemporaneous with the enclosing strata, but are evidently of subsequent formation. Certain deposits, however, somewhat similar in character have probably had a different origin, and may be regarded as beds formed prior to the deposition of the overlying rock.

Segregations of ore sometimes take place at the intersections of the main joints of certain rocks. Fig. 37 represents, in plan, an example of this kind of formation described by W. J. Henwood as occurring at Dhunpoore Mine, North-western India, where patches

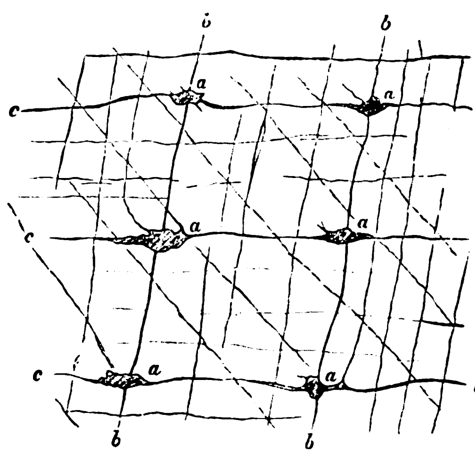

FIG. 37.—Segregations of ore at intersections of joints

of chalcopyrite and erubescite *a* occur at the intersections of a series of joints *b* and *c* which traverse nearly at right angles a somewhat calcareous clay slate. All ore deposits are subject to dislocations, and those affecting formations belonging to this class are often very similar to those experienced by true veins.

c. GASH VEINS.—Gash veins are metalliferous deposits which occur in limestone rocks only, and being confined to a single stratum or formation are necessarily limited in extent. The most typical examples of gash veins are probably those furnished by the lead deposits of the Mississippi Valley, in North America. These occur at three different horizons, of which the Galena Limestone, belonging to the Trenton Group, is the most productive. The origin of the cavities in which deposits belonging to this class have been formed, appears to be capable of a simple explanation. They are generally the bedding planes or joints of a limestone rock which have become channels through which surface waters charged with carbonic acid have flowed into a system of subterranean drainage. These joints are, generally speaking, approximately at right angles to one another, and while some are vertical, others are horizontal. In the formation of gash veins one or both members of a set of crossed vertical joints become enlarged into lenticular cavities or *gashes*; but it not unfrequently happens that the action of water containing carbonic acid not only results in the formation of vertical or horizontal galleries of moderate dimensions, but also of irregular pockets, some of which may occasionally be of considerable extent. These cavities have subsequently become filled with calcite, or sulphides of lead, zinc, and iron, originally disseminated through the surrounding or overlying country, but which were afterwards leached out and deposited in the enlarged lines of jointing of the rock. In some instances these cavities have become further enlarged subsequent to the formation of a deposit of ore in them; and in such cases the ore may either form a central pillar, a sort of curtain depending from the roof, or be found as a mass of fragments mingled with sand and clay lying at the bottom of the cavity. The Carboniferous Limestone of South-western Missouri contains layers of chert which, not being soluble in carbonic acid, sometimes forms, where the limestone beneath it has been removed by the action of acidulous waters, either a ceiling to a cavity or a sort of diaphragm across it. These frequently break down with their own weight; and, falling to the bottom, the fragments become cemented together with the ore, which thus acquires a peculiar and brecciated character.

Fig. 38 represents an ideal section of one of the usual modes of occurrence of gash veins in the Mississippi Valley.

The stratum *b* lying between *a* and *c* entirely cuts off the veins, the fissures not having penetrated into that bed. Should however the bed *c* resemble in its characteristics that which is marked *a*, similar fissures may be again found in it below *b*. In that case they will not however be continuations of the fissures found in *a*, but will, on the contrary, be a new set, originating and entirely comprised within the bed *c*. In connection with the main fissures, which may or may not be nearly vertical, lateral branches will usually be found in the same rocks, possessing similar characters with regard to their metalliferous contents.

In connection with ordinary gash veins there are usually deposits of lead ore in *flats* or *sheets*. This ore is sometimes accompanied by veinstone, and is unmixed with clay. The sheets vary much in their dimensions, but are generally elongated in one direction, and thin out gradually from the centre. Several such sheets are sometimes connected by vertical or oblique fissures containing ore, as represented in Fig. 39, descending by

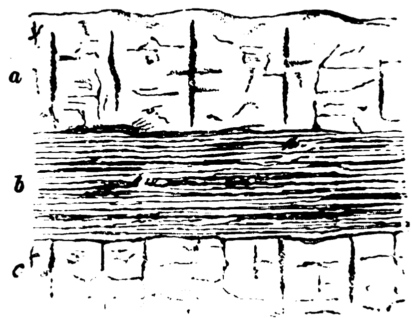

FIG. 38.—Gash veins; after Whitney.

zigzags from one stratum to another. The principal veinstone associated with galena is calcite, with occasionally a little heavy spar. Sheets of these minerals alternate with others of calamine, blende, and iron pyrites. In some places the latter minerals are more abundant than galena itself, and calamine not unfrequently becomes the predominating mineral. Casts of fossils are sometimes found in the galena from the deposits of the Mississippi Valley.

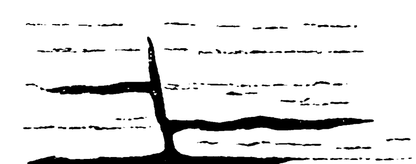

FIG. 39.—Lead ore in flats; after Whitney.

The *pipe veins* of the north of England very closely resemble gash veins, and were probably formed in the same way, as were also many of the hæmatite deposits in the Carboniferous Limestone.

d. IMPREGNATIONS.—Impregnations differ from other metalliferous deposits in not possessing any sharply defined outlines, and they consequently merge gradually into the enclosing rock.

Although met with in formations of almost every age, they occur most frequently in igneous and other crystalline rocks. In many instances the rock forming the matrix retains its general characteristic structure, the ore being disseminated through it in a more or less finely divided state. In other cases the rock becomes, to some extent, decomposed, a portion of its constituent minerals being converted into various products of alteration.

Deposits of this class may occur either independently and alone, or associated with others of a more definite character. Those which are apparently independent, and without any connection with other metalliferous deposits, extend for varying distances into the surrounding rocks, which within certain limits are impregnated with ore. Impregnations which, on the contrary, are directly in connection with other metallic deposits may either form portions of the wall rock of a vein, or be distributed along lines of fissure in communication with a lode. The ores constituting impregnations may be distributed through the rock in various forms. They may be present either as crystals or as disseminated crystalline patches, or the particles may be so finely divided as to be invisible without the aid of a powerful lens. In other cases the ores may assume the form of minute spherical aggregations, as in the Bunter Sandstone at Commern, in Rhenish Prussia. It not unfrequently happens also that rocks are stained by oxide of iron or by various copper compounds to considerable distances from large deposits of the ores of these metals; but in the majority of cases impregnations of this kind possess no commercial value. Impregnations of cassiterite occur in the mines of Saxony and Bohemia, as well as in Cornwall where, under the name of *carbonas*, they sometimes form valuable deposits. According to W. J. Henwood,[1] at the St. Ives Consolidated Mines a carbona joins the Standard lode at a depth of 78 fathoms, and at its point of junction therewith the connecting surface is not above four or five inches square. From that point it has been worked for a distance of 120 fathoms in length, with a constant inclination downward, until it reaches a depth of nearly 100 fathoms. Its greatest vertical extent is nearly ten fathoms, and its extreme width about the same; but the average dimensions may be taken at four fathoms high by ten or twelve feet in width. It exhibits few of the usual characteristics of a lode, being bounded above, below, and on either side, by ordinary granite. The deposit itself is chiefly composed of felspar, quartz, schorl, and oxide of

[1] *Trans. Roy. Geol. Soc. of Cornwall*, vol. v. 1843, p. 21.

tin, very irregularly distributed throughout the mass. In some places it contains in addition fluor spar, which is not present in the adjoining lode, chlorite, chalcopyrite, erubescite, and iron pyrites. Throughout this mass there is a gradual transition from the composition of granite to that of the carbona.

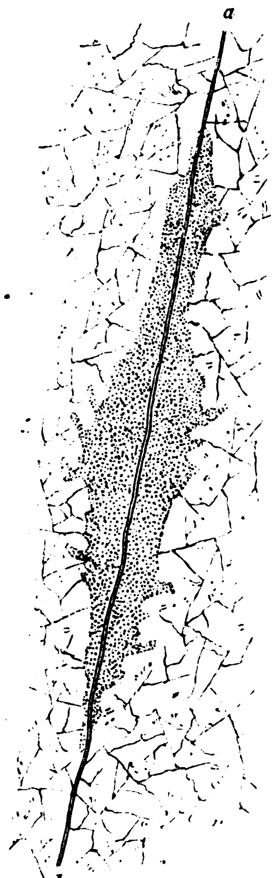

FIG. 40.—Impregnation of tin ore at East Huel Lovell.

An impregnation of granite by tinstone which occurs at East Huel Lovell, in the parish of Wendron, Cornwall, has been very clearly described by C. Le Neve Foster.[1] Fig. 40 represents a horizontal section of this deposit as seen at the 100-fathom level, in which *a b* is the *leader* or *divider*, a small vein composed of quartz and ferruginous clay varying from ¼ to ½ inch in thickness. The dotted portion is the tin-stuff, outside which is the ordinary granite of the district. This granite is well marked and encloses large crystals of orthoclase; while the stanniferous portion consists of a mixture of quartz, mica, gilbertite, and cassiterite, with a little fluor spar, iron pyrites, copper pyrites, erubescite, copper glance, and chalybite. Gilbertite, a crystalline alteration-product of felspar, is frequently abundant. There is no wall or selvage between the tin-bearing mass and the surrounding granite, the two gradually merging into one another; and, following the leader along its strike, the tin-bearing rock decreases in width until at last both walls of the vein are composed entirely of granite. The shoot of tin at the 100-fathom level was about seven fathoms in length, the richest part having a length of three fathoms and a width of nearly nine feet. In some cases the oxide of tin lay entirely on one wall, as shown in Fig. 41, but the prevailing characteristics, namely, the leader of quartz, the absence of any wall between the tin

[1] *Trans. Roy. Geo. Soc. of Cornwall*, vol. ix. 1876, p. 167.

and the granite, and the general composition of the tin ground, always remained the same. The main shoot of tin ore at East Huel Lovell has been followed from the 40-fathom level down to the 110 as one continuous pipe, and is in the shape of a long irregular cylindroid with an elliptic base generally about fourteen feet long by seven wide.

M. Daubrée, some forty years ago, first called attention to the fact that, with the exception of quartz, the minerals most constantly associated with tin ore are compounds containing fluorine, principally fluosilicates, such as lepidolite and topaz; sometimes also fluophosphates and fluorides, the latter being present chiefly as fluor spar.[1]

Boron is a constituent of the minerals tourmaline and axinite, both of which are frequently present in tin deposits; while the other

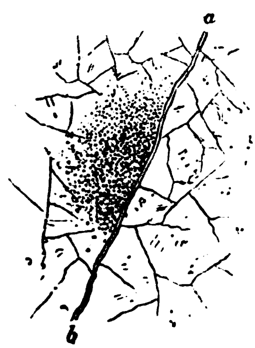

FIG. 41.—Impregnation of tin ore at East Huel Lovell.

most commonly associated elements are tungsten, molybdenum, phosphorus, arsenic, and iron. He arrives therefore at the conclusion that tin ore, fluorine compounds, and borosilicates owe their origin to the same set of reactions, and supposes that the tin, tungsten, molybdenum, boron, phosphorus, and a portion of the silicon came up through fissures from some deep-seated source as fluorides. Finally, he suggests that the present condition of *Stockworks* which consist of quartz, tin ore, silicates, fluosilicates, and borosilicates, resulted from the action of these fluorides, probably in the presence of water, on the enclosing rocks.

[1] "Mémoire sur le gisement, la constitution, et l'origine des amas de minerai d'étain," *Annales des Mines*, vol. xx. 1841, p. 65; "Études Synthétiques de Géologie Expérimentale," Paris, 1879, p. 29.

In a subsequent memoir Daubrée gives the results of numerous experiments, which he made with a view to imitating the processes by which nature may have acted in forming such minerals.[1] Instead of employing fluorides, which are not so readily made or so easily managed, chlorides were generally used, since, from the great analogy which exists between fluorides and chlorides, it was considered that any results obtained with the latter might safely be supposed to occur with the former.

The first experiment consisted in passing a current of stannic chloride together with a current of steam through a red-hot porcelain tube. In this way double decomposition was effected and crystals of stannic oxide were deposited on the interior of the tube. The crystals of oxide of tin thus obtained are sometimes colourless and transparent, and at others exhibit tints of brown or green, the different coloured specimens being all associated in the same groups. Their specific gravity is 6·72; they readily scratch glass; and when mixed with carbonate of sodium they yield a globule of tin before the blowpipe. Although exceedingly minute, the crystals so obtained exhibit well-defined faces and angles, but they are so entangled with one another that it is difficult to determine their form. The temperature of the portion of the tube on which the crystals of oxide of tin were deposited did not exceed 300° C., being rather below the melting point of lead. Titanic chloride treated in the same way yielded crystals of brookite, while a deposit of vitreous and, in part, crystallized quartz was obtained from chloride of silicon and steam. In 1851 Daubrée obtained well crystallized apatite by passing perchloride of phosphorus over lime at a dull red heat, and a mineral analogous to topaz was produced by the action of a current of fluoride of silicon on alumina at a white heat.[2]

The circumstance before referred to (p. 12) of deers' antlers more or less completely replaced by crystallized oxide of tin having been found in various Cornish streamworks, affords, however, sufficient evidence that this mineral has sometimes been deposited at ordinary temperatures. In the case in question it would appear not improbable that the production of alkaline

[1] "Recherches sur la production artificielle de quelques espèces minérales cristallines, particulièrement de l'oxyde d'étain, de l'oxyde de titane, et du quartz. Observations sur l'origine des filons titanifères des Alpes," *Annales des Mines*, vol. xvi. 1849, p. 129. "Géologie Expérimentale," p. 37.

[2] "Expériences sur la production artificielle de l'apatite, de la topaze, et des quelques autres mineraux fluorifères," *Annales des Mines*, vol. xix. 1851, p. 684. "Géologie Expérimentale," p. 48.

carbonates through the decomposition of felspars, may have been an important factor in the solution and subsequent deposition of oxide of tin.

e. STOCKWORKS.—Closely allied to the last mentioned mode of occurrence is the form of deposit known in Germany as *Stockwerk*, a term which is now generally adopted both in France and in this country. A stockwork consists of a network of small veins interlacing one another and traversing the rock in various directions; the whole of the ore present is not, however, confined to the veins, a considerable portion of it, on the contrary, being contained in the rock itself. A stockwork differs from an ordinary impregnation in not having necessarily any connection with a vein fissure, and in being usually traversed by numerous thread-like veins generally containing oxide of tin. When a rock is traversed irregularly in all directions by a network of veins, the deposit is sometimes in this country called a *floor*, and in Germany a *Trümerstock*. Examples of this kind of formation occur at the Carclaze, Beam, and Bunny Mines in the neighbourhood of St. Austell, and at various other places in Cornwall; as well as at Altenberg, Geyer, and Zinnwald in Saxony.

At Carclaze the veins traversing the granite are generally small and vary considerably in composition; sometimes they consist of schorl and quartz, at others of schorl and felspar, frequently of schorl alone, and occasionally portions of them are composed of felspar only. They are usually however a mixture of the three minerals, and generally contain a certain proportion of tinstone. As in the case of other similar deposits, the ore is seldom confined to the veins alone but is generally dispersed throughout the mass of the contiguous rock, into which, although the line of separation is often distinguishable, the veins frequently pass by imperceptible gradations.

On the whole the veins preserve a certain amount of parallelism; but there are exceptions to this, and in such cases they frequently exhibit the ordinary phenomena of heaves and slides; and when such veins unite they are often enlarged and become proportionately more productive. They are, however, generally so small and numerous and at the same time intimately mixed up with the rock-mass, that the mine has been for the most part worked open to the day, forming an excavation 250 fathoms in length, 100 fathoms in width, and about 22 fathoms in depth. These workings were formerly carried on upon an extensive scale, but of late years Carclaze has been worked chiefly for china clay, although a small

H 2

quantity of tin ore is still collected during the operations. Beam is situated about two miles north of Carclaze, and was originally quarried, but was subsequently worked in the usual way by mining; Bunny resembles Beam in its usual characteristics, but is upon a considerably smaller scale.

At Altenberg, in Saxony, the stanniferous rock, which is generally a porphyry of a greyish colour sometimes merging into greisen, a rock consisting of quartz and mica, forms a mass 1,400 feet in length, and 900 feet in width, surrounded by granite and different varieties of porphyry. This mass contains tin ore throughout its whole extent, but in such small quantities as to be almost imperceptible to the eye. It has a dark, often almost black colour, and consists of quartz, felspar, mica, specular iron ore, tin ore, and probably a little wolfram. Pyrites is sparingly disseminated throughout the rock, but the quartz, which occurs in a granular form without any apparent crystalline structure, is often the only mineral which can be distinctly recognised. Numerous veins of quartz traverse this fine-grained metalliferous rock in all directions, in which molybdenite, bismuthine, copper pyrites, fluor spar, topaz, prehnite, and nacrite, sometimes occur. The rock differs from ordinary greisen in that its texture is not quite the same, and in containing chlorite and specular iron ore. This rock, which is called by the miners *Zwitter* or *Stockwerks-porphyr*, is, as well as the neighbouring granite, traversed by numerous small and irregular veins of quartz, each of which is bordered, on both sides, by dark stripes. These dark stripes merge without any distinct line of junction into the finely granular granite; it would therefore seem as though the dark stripes were the result of impregnation by liquids traversing the vein fissure previous to its becoming filled by quartz. From analyses made at Freiberg it would appear that there is but little difference in the composition of the unaltered granite, the dark-coloured stripes bordering the quartz veins, and the zwitter.

At Geyer, the rock enclosing the numerous small string-like veins is a granite of which the felspar is much decomposed. This granite has broken through mica schist, and the associated minerals are schorl, fluor spar, oxide of tin, and apatite. Cassiterite is not only present in the small parallel veins, but is also disseminated through the adjacent rock. The veins rarely exceed two inches in width and gradually merge into the granite.

At Zinnwald, tin ore is obtained from a granitic rock sometimes classed as a greisen, containing but a very small proportion of felspar, and forming a flattened dome-shaped mass, which rises through a larger one of porphyry. The whole of this rock is frequently stanniferous, but the most productive deposits exist in the form of concentric zones, none of which exceed twelve inches in thickness. Seven of these zones or foliations, which Burat[1] regards as contemporaneous with the granite, and from which he believes they were separated by a sort of liquation, are of sufficient importance to allow of being worked for tin. Subsequently to its consolidation the mass of the granite has been faulted by various fissures, now filled with clay and other débris, so that the metalliferous zones have experienced numerous throws.

At the Polberrow Mines in the parish of St. Agnes, Cornwall, a pale blue slate of silky lustre is traversed by numerous small tin veins. This rock extends to Trevaunance, forming the sea-cliff between that place and Trevellas Coombe, and contains many small quartz veins in addition to several lodes and cross-courses. The way in which these tin veins occur in slate rock is well illustrated in Fig. 42, which represents a specimen from this

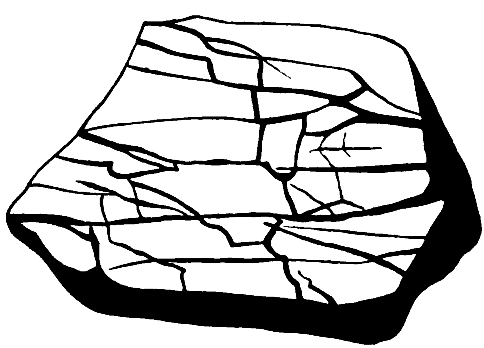

FIG. 42.—Tin veins in clay slate, Polberrow.

locality, of which a lithograph is given by Henwood, in his valuable monograph on the Metalliferous Deposits of Cornwall and Devon. Writing in 1838, this author makes the following observations relative to the workings at Polberrow:—"In pursuit of these little tin veins the excavations have been so numerous and extensive, that a mass of rock extending from the surface to sixty fathoms deep, being unsupported, is now slowly subsiding. The portion thus in motion is perhaps sixty or eighty fathoms in diameter, and its descent at the rate of six or eight feet in a month. The miners

[1] "Géologie Appliquée," Paris, 1855, p. 339.

still continue their labours in the moving mass." This appears to be the only stockwork ever extensively worked in clay slate, and it would be interesting to determine by means of analysis whether the whole of the oxide of tin is contained in the small veins, or whether a portion of it may not be enclosed in the slate itself.

f. FAHLBANDS.—The celebrated silver mines of Kongsberg, in Norway, discovered in 1623, and worked with comparatively little interruption from that date to the present time, are situated in a district consisting chiefly of gneiss, gabbro, mica schist, hornblende schist, talc schist, and chlorite schist. The silver ores occur in what are known as *Fahlbands*, which consist of parallel belts of rock, of considerable width and extent, impregnated with sulphides of iron, copper, and zinc, and sometimes also with those of lead, cobalt, and silver. The iron pyrites often becomes, to some extent, decomposed near the surface, giving rise to the formation of hydrated ferric oxide and producing a kind of gossan, which is locally regarded as an indication of the presence of silver ores. These fahlbands, or grey beds, have a direction very nearly north and south. They are irregular in their dimensions, the greatest breadth of any one of them being about a thousand feet; but they constantly preserve a considerable degree of parallelism with one another, and may be traced upon their line of strike, for a distance of several miles.

The amount of ore disseminated through such beds is usually very small, and in but a few localities only has it been found sufficiently concentrated to admit of its being profitably worked. In the Kongsberg district there are several of these fahlbands, parallel in strike and inclination with the gneissoid and schistose strata in which they occur, and subject to the same local disturbances of stratification. They are themselves traversed by fissure veins containing silver ores, and long experience has shown that these are productive only where they intersect fahlbands. From this circumstance it becomes evident, not only that the composition of the lode is dependent on the nature of the adjacent rock, but also that the metalliferous portions of them were, in all probability, originally derived from the fahlbands through which they pass. The lodes, which are numerous, course nearly east and west, almost at right angles to the strata and fahlbands, and generally dip towards the south, although a few of them incline in the opposite direction. As a rule they are but a few inches in breadth, seldom exceeding a couple of feet, and their narrower portions are usually richer in silver than the broader parts, which are chiefly made up of non-metalliferous veinstone. Their breadth is stated to increase up to a certain depth and then gradually to diminish; the portions having a thickness of about one inch being on an average the richest. When two such lodes intersect within the limits of a fahlband, the result is often a considerable pocket of ore. The lodes are without selvages, and are firmly attached to the wall rock, which for some distance is often impregnated with silver ores.

The district around Skutterud and Snarum consists of crystalline schists which vary between gneiss and mica schists, but which sometimes pass into hornblende schists. These, whose course is nearly north and south, and of which the dip is almost perpendicular, contain metalliferous zones similar to those of Kongsberg. They differ from them, however, in that the ores of cobalt which are disseminated through them will, in certain places, pay the expenses of extraction, while the fahlbands of Kongsberg are only important from enriching the lodes passing through them. The breadth of these fahlbands varies considerably, although their width cannot always be accurately determined, since a gradual transition takes place from the metalliferous to the totally barren rock. They follow the strike and dip of the schists, and are sometimes as much as thirty-six feet in width. Veins are altogether wanting in these fahlbands, and on the outer edges of the cobaltiferous beds are others containing mispickel, which is entirely free from cobalt. The principal fahlband is known to extend for a distance of six miles, and is bounded on the east by a quartzose diorite, which protrudes into the bed in the form of irregular masses, and as dykes, traversing it in a zigzag course. This metalliferous band is also intersected by dykes of coarse-grained granite, which contains no ore, but whose branches sometimes penetrate into the diorite.

g. CONTACT DEPOSITS.—Contact deposits are metalliferous accumulations often found between the planes of contact of dissimilar rocks. In deposits of this class the ore is usually concentrated between two formations differing in geological age, and unlike in their mineralogical characteristics. When strata have been uplifted and have become metamorphosed through the agency of a central intrusive mass, an irregular band of metalliferous ore will sometimes be found extending along the line of contact between the eruptive and altered rocks, while in other cases it may be met with at some inconsiderable distance from the line of junction, with which, however, it preserves a general parallelism. Fig. 43 represents an ideal section of a line of contact between a stratified and an igneous rock, in the immediate vicinity of which occur the metalliferous deposits *a*.

Some remarkable deposits of this character are met with near Framont, in the Vosges, where masses of specular iron ore surround a central boss of quartz-porphyry, which has tilted the stratified rocks, and specular ore has been introduced into all the resulting fissures and cavities, which are frequently lined with beautiful crystals of that mineral. The sheets and strings of copper which are concentrated at the junction of trap and sandstone at some points on

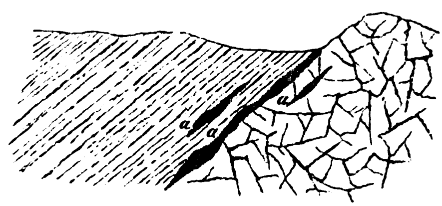

FIG. 43.—Contact deposits.

the south shore of Lake Superior, afford an example of the deposit of a native metal along the contact planes of two dissimilar rocks. The copper ores of Monte Catini, in Tuscany, also belong to this class of deposit, being developed along the line of outcrop of certain gabbros, which Burat appears to regard as resulting from the metamorphic action of serpentine upon strata of cretaceous age.

There is considerable diversity of character among deposits of this kind, the chief distinction between them arising from the circumstance that in some cases the ore has been segregated from one or other of the neighbouring rocks, while in others it has apparently come from a foreign source, and been deposited in more or less continuous sheets in cavities formed between the surfaces of adjacent rocks. To the first of these classes appear to belong the argentiferous ores of Leadville, Colorado, which S. F. Emmons regards as having been deposited from aqueous solutions coming from above, which derived their metallic contents from neighbouring eruptive rocks.[1]

The celebrated quicksilver mines of Almaden, situated in the province of La Mancha near the frontier of Estremadura, Spain, are worked on three parallel bed-like formations belonging to the class of contact deposits. They occur at the junction of Silurian slates and sandstones with a metamorphic rock generally

[1] "Geology and Mining Industry of Leadville, Colorado," *Annual Report of the Secretary of the Interior*. Washington, 1882, p. 234.

regarded as a sandstone metamorphosed by the action of a mass of diorite upon which it rests.

h. CHAMBERS OR POCKETS.—Chambers in limestone rocks form in many countries receptacles for the ores of various metals, but no where are there such striking examples of this class of deposit as those found in the western mining districts of the United States of America. After carefully studying these masses of ore *in situ*, Dr. Newberry has arrived at the conclusion that they constitute a distinct and important class which should be added to the catalogue of forms of ore deposit heretofore described. Deposits of this class when of large size are in Germany included under the name of *Stöcke*, while those of smaller dimensions are named either *Butzen* or *Nester*.

Among the most striking examples of these chamber mines are the Eureka Consolidated, and Richmond, in Nevada, and the Emma, Flagstaff, and Kessler Cave Mines in Utah, &c. In all of them the ore-bodies are found filling, more or less completely, irregular chambers in limestone, and the aggregate annual production of such deposits is now very large. Ore to the value of £200,000 is said to have been extracted from one of the chambers of the Eureka Consolidated, and a still larger amount from the great chamber at the Emma Mine. Newberry believes these deposits to have been formed in the following way:—

A stratum of limestone more than usually soluble in atmospheric waters containing carbonic acid, has at some period been honeycombed into chambers and galleries, such as those which traverse the limestone plateau of Central Kentucky, of which the Mammoth Cave is a well-known example. Subsequently the rock was broken through and uplifted by the subterranean forces which have disturbed all important mining districts, and through the fissures thus formed mineral solutions ascended and flowed into any cavity that might be open to receive them. Whenever these fissures traverse an insoluble rock, they have become fissure veins, whereas, when cavernous limestone was broken into, its open galleries and caverns were more or less completely filled with ore. It has been suggested that the caves now holding these ores may have been produced by the action of the same metalliferous solutions from which the ores were deposited. This, however, he does not think probable, since many of the cavities are without ore and have their sides incrusted with crystals of calcite; and even where ore is met with the surrounding walls are always hard and unimpregnated with ore. He concludes therefore that the chambers were formed, like modern caves, by surface waters, and that at the time the country was uplifted and the rock shattered some of them only were broken into; these alone received the metalliferous solutions and ultimately became, at least partially, filled with ore, while those which were not in communication with the metalliferous channels have remained empty. The character of the ores contained in these chambers varies as much as it does in ordinary fissure veins, thus showing that the nature of the metalliferous solutions was not always in different localities the same. There can be no doubt that argentiferous galena was the ore most abundantly deposited in these chambers, but in some cases it was associated with large quantities of iron pyrites, while in others this mineral is almost entirely absent.

The ratio of gold to silver varies greatly in such ores; those of the Eureka Mine are rich in lead, and contain much iron, while the aggregate value of the precious metals is about £14 per ton, of which one half is represented by gold and the other half by silver. The ores of the Emma Mine were richer in lead, and contained less iron and a little copper, but much more silver and less gold. Similar differences occur in all the chamber mines, but in every instance the ore has become thoroughly oxidized. In some of the neighbouring fissure veins, however, the decomposed ores of the chambers are represented by unaltered masses of galena and iron pyrites, in which form the ores were doubtless originally deposited in the caverns of the limestone; in such veins the galena usually carries the silver, and the pyrites, the gold. The enormous production of silver and gold from the chamber mines already worked in the United States, sufficiently demonstrates the great importance of this class of deposit, but should the theory suggested by Dr. Newberry be correct, they cannot be expected to extend to such great depths as the ore-bodies of fissure veins; since the excavation of the limestone if produced by atmospheric water, cannot extend beyond the zone traversed by surface drainage.

General Conclusions.—It is evident that, although convenient for the purposes of description and for fixing our views within certain limits, no classification of ore deposits can, in all cases, be quite satisfactory, and this becomes at once apparent when we consider the numerous points of resemblance which exist between their several varieties. A segregated vein, if everywhere following the stratification or foliation of the enclosing rocks, may be readily mistaken for a bed; if, however, during any portion of its course it be found either to cut across the stratification or foliation, or to enclose fragments of both the overlaying and underlaying rocks, it becomes evident the deposit can only be regarded as a vein.

The two essential requisites for the formation of an unstratified ore deposit would appear to be, in the first place, the existence of a metalliferous rock, and, in the second, the presence of suitable cavities in which an accumulation of mineral can take place from solution. Such cavities may either assume the form of ordinary vein fissures, or that of chambers or pockets.

Fissures may cut distinctly across the strata independently of bedding and may become true fissure veins; or they may conform to the stratification of the enclosing rocks and ultimately give rise to deposits of the class known as segregated or bedded veins.

Fissures owing their origin to deep-seated causes will follow the stratification of the rock, or will run across it, according to the direction of the forces producing them; fissures of a third description may be formed along the line of junction of an eruptive rock with a sedimentary one, or between two rocks of eruptive origin but of different ages. In all cases the process of filling by infiltration will probably be the same, excepting that in the deeper fissures, more especially in those in the vicinity of eruptive rocks, it is not unreasonable to suppose that through the instrumentality of highly heated waters a portion of the ore and veinstone may have been derived from rocks lying at considerable distances and at very great depths. It is likewise not improbable that changes in local conditions may sometimes result in the removal of a deposit from one position and its re-deposition in another. In the case of contact deposits there appears to be no reason for believing that the juxtaposition of dissimilar rocks has generally any direct influence on the formation of ores; on the contrary, it will be understood that between the surfaces of approximate contact there will often be spaces suitable for the reception of minerals, and should one or both of the adjoining rocks be metalliferous, and other circumstances favourable, deposits of ore will be the result.

Where, as at Leadville, Colorado, a great thickness of metalliferous porphyry or of other similar rock overlies beds of limestone in which large cavities have been produced by the action of carbonic acid contained in the surface waters, these may become the repositories of accumulations of ore which has been washed out from a superincumbent crystalline rock. In other cases, as in certain mines of Nevada and Utah, the metalliferous solutions may have reached the cavern-like receptacles of ore from below and through fissures in rocks not readily acted upon by carbonic acid.

Gash veins would appear to be the result of the action of waters containing carbonic acid upon certain fissures in limestone, which subsequently become more or less completely filled with minerals derived from rocks in their immediate vicinity.

Impregnations may be regarded, generally, as concentrations by chemical agencies of metalliferous minerals previously disseminated either through the same or through a neighbouring rock. This concentration appears to have been often caused by the percolation of metallic solutions through the substance of the various rocks, but as regards "carbonas" these seem to have frequently arrived from some distance through fissures in direct communication with lodes.

Stockworks are sometimes little more than patches of crystalline rock containing an unusual proportion of an ore which is more sparingly disseminated throughout its mass; any minute fissures which may occur in such deposits becoming, as in the case of fahlbands, metalliferous by a process of segregation. In certain cases, however, as at Altenberg, a portion of the stanniferous solution has apparently reached the stockwork from a distance through fissures subsequently filled with quartz. As is exceptionally the case with certain fahlbands, eruptive rocks sometimes contain patches sufficiently impregnated with an ore to admit of being advantageously worked. Such metalliferous patches are probably in some cases the result of an originally unequal distribution of an ore forming one of the constituents of the rock, but there does not appear to be sufficient ground for believing that ore deposits in any other form have been directly produced by eruptive action.

PART II.

ORE DEPOSITS OF THE PRINCIPAL MINING REGIONS.

In selecting for description some of the more important ore deposits of the world, they will be grouped in accordance with their geographical distribution, and will be chosen either on account of their economic importance, or because they exhibit unusual and instructive phenomena.

The principal deposits of the various mining countries will be described in the following order:—

EUROPE.—The United Kingdom, France, Belgium, German Empire, Austro-Hungarian Monarchy, Italy, Greece, Spain, Portugal, Scandinavia, Russian Empire—Asia in Part.

ASIA AND OCEANIA.—Indian Empire, Straits Settlements, Dutch East Indies, Japan, &c., Australasian Colonies.

AFRICA.—Algeria, Cape of Good Hope.

NORTH AMERICA.—United States, Dominion of Canada, Mexico.

SOUTH AMERICA.—Brazil, Chili, Bolivia, Peru, Guiana, &c.

EUROPE.

THE UNITED KINGDOM.

The most important mines of the United Kingdom are situated in the counties of Cornwall and Devon, in Shropshire, Yorkshire, Derbyshire, and North Lancashire, as well as in Westmoreland

and Durham. Mining is also extensively carried on in Anglesea and various other parts of Wales, in the Isle of Man, in the south-west of Ireland, and the south and west of Scotland.

ENGLAND.

Silver mines were worked in Britain before the invasion of the island by the Romans, and gold must have been well known to the inhabitants of this country before the arrival of Cæsar, since coins of that metal were then in circulation among them. Cæsar and Strabo agree in stating that the Britons obtained their copper from foreign sources, and iron is described by the former as being so rare as to be sometimes employed as a medium of exchange; a century later, however, it was so common as to have become an article of export. Tin was anciently the most important metallic production of Great Britain, and a desire to obtain possession of the mines producing it, and thereby becoming independent of the Phœnician monopoly, appears to have first induced the Romans to visit the island. About the middle of the sixteenth century mining was less intelligently conducted than on the Continent, as we are told by Sir John Pettus[1] that "About the third year of *Queen Elizabeth*, she, by the advice of her Council, sent over for some *Germans* experienced in *Mines*, and being supplied, she, the tenth of *October*, in the sixth of her reign, grants the *Mines* of eight Counties, besides those in *Wales*, to *Houghstetter*, a *German*, &c., whose name and Family still continue in *Cardiganshire;* and doubtless we had much of our knowledge from their Predecessors, who revived this work in *Cardiganshire.* They also entered upon another work of *Copper* at *Keswick*, in *Cumberland*."

In addition to having been long pre-eminent as a tin-producing country, England was, for a period somewhat exceeding a century, likewise the largest producer of lead, copper, and iron ores. Although still yielding a more considerable amount of iron ore and producing a greater quantity of pig iron than any other country in the world, as far as the other metals are concerned England has at the present time various formidable and successful rivals. Among European countries Spain may be cited as producing larger quantities of lead and copper, while recent colonial enterprise has resulted in the discovery of large and exceedingly rich deposits of tin ore in Australia.

CORNWALL.—The metalliferous rocks of Cornwall comprehend

[1] "Fodinæ Regales," 1670, p. 20.

granite and slates, associated in some places either with hornblendic rocks or with *elvans* (quartz-porphyries), which usually form broad dykes intersecting indifferently both granite and slate.[1] Granite occurs in four principal masses, besides several smaller ones, its chief constituents being quartz, felspar, and mica; although in addition to these schorl is everywhere more or less abundant. The felspar and mica of Cornish granites are of at least two kinds, and the granitic ground-mass sometimes includes large crystals of both mica and tourmaline. The granite is for the most part somewhat coarse-grained, but varies considerably in this respect in different localities, while the more coarsely crystalline rock is not unfrequently traversed by granite veins of a much finer texture. Spheroidal masses of schorl rock are sometimes enclosed in the granite. Two distinct series of joints intersect the granite nearly at right angles, dividing it into approximate cubes, while others, in intermediate directions, again subdivide it more or less irregularly. The granite of this region frequently exhibits a foliation which roughly approximates to the contour of the surface and imparts to the rock a somewhat gneissoid character.

The slates, which are locally known as *killas*, usually rest on the granite at a considerable angle, but in some cases the junction is nearly vertical, while in others the two rocks are, in the immediate vicinity of their boundaries, considerably mixed. Near the line of junction the granite is not unfrequently extremely fine-grained, while the slate often becomes hard and massive, but differs from the granite in general appearance, as well as in being also much darker in colour. Veins of granite frequently penetrate the slate, and masses of the one rock are sometimes enclosed in the other. In one district, at a considerable distance from any known large body of granite *in situ*, numerous detached spheroidal boulders of that rock have been found enclosed in slate. No general description can be given of the mineralogical composition of the slates of Cornwall, since the nature and proportions of their several constituents are seldom constant over any considerable area. Among their recognizable minerals, however, quartz, felspar, mica, chlorite, schorl, and hornblende are the most conspicuous. In the vicinity of granite the slates are frequently of a green, brown, purple, or violet hue; but at more considerable distances from it they are

[1] The metalliferous districts of Cornwall have been more carefully described by W. J. Henwood than by any other observer, and I have much pleasure in acknowledging my obligations to his work, "On the Metalliferous Deposits of Cornwall," *Trans. Roy. Geol. Soc. of Cornwall*, vol. v., and to his *Address, Royal Institution of Cornwall*, 1871, for much important information.

often of a grey, bluish-grey, deep-blue, brownish-yellow, or buff colour, and in some localities contain fossils, chiefly of Devonian age. Certain of these slates are distinctly crystalline and possess an imperfect cleavage, while others are highly fissile; all are, however, more or less interlaminated and veined with quartz. The planes of bedding almost invariably dip from the granite, the various layers of slate thus mantling round the slopes of the granitic hills. Sandstones sometimes occur interstratified with the slates, which are also occasionally traversed by dykes of diabase.

Quartz-porphyry usually occurs in the form of dykes known as *elvan courses*, which are sometimes only a few feet in width, but are generally much wider. Less frequently elvan has been met with in apparently isolated masses. Elvan courses traverse granite as well as slate without interruption, and, in one case at least, two lodes would appear to have been intersected by an elvan. Dykes of this rock frequently conform both in direction and dip to one series of joints in the rocks which they traverse, but are rarely conformable with the cleavage planes of the slate. Elvan courses sometimes divide into branches or offshoots, but this occurs less frequently than in the case of lodes. When enclosed in slate, elvans are usually, to a large extent, composed of a compact felspathic ground-mass with quartz and a little schorl or mica, enclosing white, buff, pink, or dove-coloured felspar with crystals of quartz, which are often double-pointed, and of which the faces and edges sometimes appear to be slightly rounded. When passing through granite, quartz and felspar still prevail, and mica and schorl are abundant, as well as are also porphyritically-enclosed crystals of felspar and quartz; but the texture of the ground-mass is usually finer than it is when traversing slates. In both rocks, however, elvan is coarser in grain near the centre of the mass than in the vicinity of its sides.

Numerous joints traverse the elvans in all directions, dividing them into blocks of irregular form; these crevices are in some cases faced with schorl, while in others they are filled either with a white or a ferruginous clay. The quartz of elvans contains fluid-cavities very similar to those found in that mineral when occurring in granite. Throughout the mining districts of Cornwall the run of the elvan courses is a few degrees north of east and south of west, but in other parts of the county they vary considerably from this direction. Their dip is less than that of the lodes by which they are intersected, but greater than the dip of the cleavage planes of the slates which they intersect.

The serpentine of Cornwall is traversed by numerous veins and branches, which sometimes contain native copper, but this metal does not occur in sufficient quantities to entitle the rock to rank among the metalliferous series of the county. Veins of fine-grained granite sometimes penetrate not only the outer edges of the granitic bosses but also the adjoining fossiliferous rocks, including the Culm series. The elvans hold their course straight through the granite and the granitic veins, and these are again traversed by veins containing tin and copper ores. The lodes are, therefore, newer than the elvans, and the most ancient mineral veins of Cornwall are consequently younger than the Carboniferous period; they are, however, probably not more recent than the Permian, since no lodes have been discovered in the sandstones belonging to the Poikilitic group.

In certain exceptional instances it might, at first sight, appear that elvans were posterior to tin veins, but the observations of Sir H. T. De la Beche led him to an opposite conclusion, and he has shown how the cases which have been brought forward in support of that view may be otherwise interpreted.[1] Tin ore occurs disseminated through granites, elvans, and slates, as well as in minute veins in these rocks. Copper ores are sometimes sporadically distributed through the granites, elvans, and slates in the same way that these rocks are impregnated with tin ore. Such impregnations of copper, however, seldom possess any commercial importance.

The principal repositories of the various ores of Cornwall are lodes, which consist to a large extent of quartz, and extend without interruption through every rock of the metalliferous series; they however, in some degree, partake of the characteristics of the different rocks through which they pass. Notwithstanding that workings often extend for considerable distances on lodes corresponding in direction, it is by no means certain that any individual lode has ever been traced for a length of above a mile. Every lode throws off branches and strings into the adjoining country rock, and this frequently occurs to such an extent that instead of remaining a single *champion lode* the vein becomes divided into a complex and irregular network. A lode will also often dwindle to a mere line, while some of its offshoots become enlarged, and finally exceed, both in size and richness, the vein from which they originally separated. It is by no means unusual for a lode to divide immediately at its point of intersection with a cross-course,

[1] "Report on the Geology of Cornwall and Devon," 1839, p. 310.

on one side of which it will be united, while on the other it is divided into several branches.

Lodes which are approximately parallel in direction dip at various angles or in different ways, and consequently they not unfrequently intersect one another. The results of such intersections are exceedingly various: sometimes such veins unite and continue together for some distance, but at length separate. Not uncommonly one lode is displaced horizontally, or thrown vertically, by the other, while occasionally both are disordered and lose their distinctive characters at the point of intersection. Generally speaking, lodes which yield a mixture of the ores of tin and copper are wider than those which contain ores of only one of these metals. The lodes of Cornwall are wider in slates than in the granite, and their average width is greater within 100 fathoms from the surface than at any greater depth hitherto attained. Henwood furnishes the following figures as the result of his investigations relative to the thickness of Cornish lodes:—

Lodes yielding ores of both tin and copper	average	4·7	feet	in width.
,, ,, tin ores	,,	3·0	,,	,,
,, ,, copper ores . . .	,,	2·9	,,	,,
,, in granite	,,	3·1	,,	,,
,, in slate	,,	3·7	,,	,,
,, at less than 100 fathoms deep .	,,	3·9	,,	,,
,, at more ,, ,, ,, . .	,,	3·3	,,	,,

On passing from one rock to another, or from riches to poverty, the width of a lode frequently changes, but under ordinary circumstances a lode commonly maintains, approximately, its characteristic breadth. The direction of lodes in the different mining districts are not perfectly identical, nor are all those occurring in the same neighbourhood strictly parallel.

The central portions of the county are traversed by two systems of veins, namely, champion lodes and *counter lodes*, each of which maintains approximately its own normal range; but, even in the most western district, the veins exhibit a certain degree of divergence. Notwithstanding that there is scarcely a point of the compass towards which some lode is not known to tend, and that the lodes in many localities have an approximate coincidence, their mean direction differs materially in various parts of Cornwall.

The mean direction of the lodes in different parts of Cornwall are given by Henwood as follows:—

St. Just . . .	35° S. of E., N. of W.	Redruth . .	22° N. of E., S. of W.
St. Ives . . .	8° S. of E., N. of W.	St. Agnes . .	22° N. of E., S. of W.
Marazion . .	1° N. of E., S. of W.	St. Austell .	13° N. of E., S. of W.
Gwinear . .	2° S. of E., N. of W.	Caradon . . .	18° N. of E., S. of W.
Helston . . .	16° N. of E., S. of W.	Tavistock . .	9° N. of E., S. of W.
Camborne . .	20° N. of E., S. of W.		

Their average bearing is about 5° N. of E., S. of W., a range which does not materially differ from that of the granite outcrops which at intervals make their appearance between Dartmoor and the Land's End, and also not unlike the course of a line drawn directly through the centre of the county. Lodes present as many flexures in their downward course as in their horizontal direction, and vary in dip from an inclination of less than 45° with the horizon to 90°; the average being probably about 70°. Sometimes, although less frequently, lodes dip in opposite directions in different parts of their range. Both lodes and cross-courses dip more frequently towards the granite than away from it, and veins which maintain a nearly meridional direction are in Cornwall more highly inclined than those coursing more nearly east and west.

Lodes intersecting dissimilar rocks obliquely to their line of junction are sometimes slightly deflected, and for a short distance occasionally pass between them, but they suffer no interruption and soon resume their original direction. In such cases the rocks often occupy corresponding positions on both sides of the vein; sometimes, on the contrary, a faulting of the strata has taken place along the course of the lode, and the horizontal and vertical range of the rocks on its two sides may be very different. Both the composition and structure of lodes is materially influenced by the rocks in their immediate vicinity.

Those parts of the lodes of Cornwall which are most uniform in composition consist chiefly of crystalline quartz containing many fluid cavities, and in such places a distinctly jointed structure of the veinstone is frequently apparent; but where the filling of the vein fissure is made up of more heterogeneous materials this characteristic is less commonly observed. The quartzose portions of veins are sometimes divided into combs which curve, unite, separate, and again fall together in such a way that, without being strictly parallel, the thicker parts of certain layers adapt themselves to the thinner portions of others.

When lodes coincide in direction with the joints of the enclosing rock, their walls are usually smooth and well defined, but when the joints disappear there is generally a gradual transition from the veinstone to the country rock. Lodes not only afford instances of foliation parallel to their strike, but they are also frequently traversed by cross-joints imparting to them, in some degree, the appearance of horizontal bedding. Fissures in the vicinity of the line of separation between veinstones and the country rock are often filled with flucans which, like slickensides, are frequently scored with curved and unconformable striæ.

Many lodes, from enclosing portions of the adjoining country rock, present a brecciated appearance. Lodes of this character are not uncommon in both granites and elvans, but are most conspicuous in slates. In some instances these inclusions have the form of roughly lenticular or sheet-like bodies; occasionally they are sharply defined, while sometimes they appear to pass by imperceptible gradations into the surrounding veinstone. Less frequently they are enclosed in successive accretions of quartz, each distinguishable by some peculiarity of either structure or colour. Small cavities surrounded by botryoidal concretions of agate-like silica, often lined with crystals of quartz, occur at intervals between the fragments of included rock. When these fragments consist of slate, their planes of cleavage are almost always coincident with those of the enclosing country rock, but when the country consists of either granite or elvan, the pieces included in the lode being of the same material, their general resemblance to the veinstone is so close that their relations are less easily detected. When such phenomena occur on the line of contact of different rocks, their planes of junction observed in the enclosed horses are on precisely the same horizon as their counterparts in the rock by which the lode is enclosed. Felspar is abundant in all lodes passing through granites and elvans, but in slate quartz is the predominating veinstone. The outcrops and shallower portions of nearly all lodes are usually to some extent composed of gossan, consisting of an earthy iron ore mixed with granular quartz, and frequently containing oxide of tin with other metalliferous minerals.

When tin lodes traverse the granite, their most productive veinstone is usually pale-green or brownish-red felspar, imperfectly crystalline, and associated with quartz and schorl; but quartz and schorl are sometimes abundant ingredients, and occasionally quartz prevails. The tin oxide is usually present in the form of crystalline granules which seldom exceed the size of a pea, but are more often microscopically minute. In slate tin lodes consist chiefly of capel or quartzose slate, chlorite, quartz, and schorl, in thin alternations. The ore is disseminated in even more minute particles among these minerals than it is in the lodes of which the country rock is granite. Copper lodes in granite have almost always an outcrop of gossan, which sometimes extends to considerable depths; but the quartz associated with them is rarely so friable as it is in similar deposits enclosed in slate. The cavities which occur in this slightly coherent material often contain earthy brown iron ore, coloured clays, black copper ore, and malachite. At greater depths fluor spar is not an uncommon veinstone, while black copper ore is frequently succeeded by chalcocite, and this by copper pyrites. In one of the most important mining localities of Cornwall, the outcrops of many of the lodes were anciently worked for the tin ore which they afforded near the surface. On proceeding downwards, however, the tin became gradually replaced by copper ores, of which the lodes were for some time most productive repositories; still deeper, tin ore re-appeared, and for many years this has been almost the only metalliferous product of the neighbourhood. Copper lodes in slate often contain large quantities of spongy, pale-brown or yellowish iron ore, with a small proportion of oxide of tin, and iron pyrites in considerable abundance, with more or less blende and galena. Their other constituents are quartz, which in the more productive lodes is often exceedingly friable, and is mixed with *prian* or felspathic clay; less frequently with chlorite, and still more rarely with fluor spar. Near the surface these minerals are often associated with iron pyrites, earthy black copper ore, and malachite, and these are succeeded by chalcocite, which, together with all the other metalliferous minerals, is ultimately replaced by chalcopyrite. Notwithstanding that the ores of tin and copper often affect different lodes, and even different rocks, they are, nevertheless, intimately associated in some of the most productive veins of the county. Ores of lead for the most part occur at some distance from the granite, and are principally limited to groups of lodes traversing slaty rocks in a different direction from those producing tin and copper.

It has been before stated that the most compact portions of the lodes of Cornwall are chiefly siliceous, and that they are sometimes composed entirely of quartz; occasionally, however, the whole substance of a lode becomes metalliferous. The alteration from poverty to riches is seldom a sudden one, since the veinstone in the neighbourhood of large bodies of ore usually becomes increasingly impregnated with the same mineral as it approaches the larger mass. In all lodes, whatever may be the nature of the ore which they produce, the most highly inclined portions are the most productive; and almost all bodies of ore, whether of tin, copper, or lead, have an end-long dip, usually approximating to the foliation of the enclosing granite, or to the bedding or cleavage-planes of the surrounding slates. Lodes and branches are frequently richer at their junction with one another than they are elsewhere; particularly when they come together horizontally or on their dip so as to form an acute angle. When lodes of a soft or granular character pass into a rock of more than ordinary hardness, they frequently divide into numerous branches; while the same effect is sometimes produced by the passage of a lode into unusually soft strata.

Rocks possessing a considerable degree of hardness are more frequently productive of tin than they are of copper, and, both in granite and in elvan, a well-defined porphyritic structure is regarded by miners as an unfavourable indication; while in both rocks a gradual blending of the included crystals with the surrounding ground-mass is considered an encouraging circumstance. Transverse joints often exercise an unfavourable influence on the production of a lode, and a course of ore sometimes terminates abruptly at such a fissure. During many years the chief produce of two important and almost adjoining tin mines in Cornwall, was obtained from deposits of which examples on a large scale are not met with in other parts of the county. These deposits, which are locally known as "carbonas," will be again referred to in connection with the tin deposits of the St. Ives district.

Veins which chiefly consist of quartz, and which with rare exceptions yield neither ores of tin nor copper, are in the St. Just district called *guides*, while in the neighbourhood of St. Ives they are known as *trawns*, and in other parts of Cornwall as *cross-courses*. When such veins consist of clay only, they are called *flucans*. In the following table Henwood applies the term *cross-vein* to both varieties. The mean directions of cross-veins in different parts of Cornwall are as follows:—

St. Just . . .	26° N. of E, S. of W.	Redruth . . .	35° S. of E., N. of W.
St. Ives . . .	38° S. of E., N. of W.	St. Agnes . .	39° E. of S., W. of N.
Marazion . .	41° S. of E., N. of W.	St. Austell . .	21° S. of E., N. of W.
Gwinear . .	43° E. of S., W. of N.	Menheniot . .	3° N. of E., S. of W.
Helston . . .	21° S. of E., N. of W.	Caradon . . .	13° E. of S., W. of N.
Camborne .	34° E. of S., W. of N.	Callington . .	43° S. of E., N. of W.

Their average bearing throughout the county is about south-east to north-west, which does not differ materially from that of one of the most distinctly developed series of joints in the rocks. The average inclination of cross-veins maintaining the general range is about 80°, whereas that of those which run more nearly east and west scarcely exceeds 60°. Their dip is more frequently towards the granite than in the contrary direction.

Cross-veins are wider in granite than in slate, and at great depths than near the surface.

The mean width of cross-veins	in granite averages	4·9	feet.
" " " "	slate "	3·5	"
" "	at less than 100 fathoms deep	4·0	"
" "	at more " "	4·4	"

Cross-veins, like lodes, partake of the nature of the different rocks through which they pass; thus in granite, notwithstanding the occasional occurrence of quartz, the principal constituents are the minerals of which granite is composed. In homogeneous slate, on the contrary, they are not unfrequently flucans consisting of triturated slate. Sometimes cross-veins are only developed at certain depths from the surface, and disappear both horizontally and vertically within very short distances.

Small quantities of copper and silver as well as of the ores of these and other metals occur in cross-veins, but they are frequently, although not always, limited to those portions of the vein which pass through lodes in which such metals and ores prevail. A large proportion of the richest lead veins in the county of Cornwall have, however, nearly the same direction and mineral characteristics as the principal cross-veins. Cross-veins, intersecting both the rocks and lodes through which they pass, when composed of cavernous quartz, afford almost the only natural channels for the ready circulation of underground waters; on the other hand those portions which have been filled with flucan are so thoroughly impermeable that they are, for this reason, not unfrequently chosen as the boundaries of areas leased for mining purposes. Slides have been observed in the schistose rocks of certain mining districts only.

It is of great importance that the miner should be in a position to judge whether the chances of successful search for a severed vein are greatest towards the right or towards the left hand, and the following information relative to this subject will not be without interest.[1] Out of 272 lodes recorded by Henwood as being divided by cross-veins in different parts of Cornwall,—

57	or 0·20	of the whole number were intersected but not heaved.				
135	„ 0·50	„	„	were heaved towards the right hand.		
80	„ 0·30	„	„	„	„	left hand.
181	„ 0·67	„	„	„	„	greater angle.
34	„ 0·13	„	„	„	„	smaller angle.

The following are the results of the intersection of lodes, affording ores of different metals, by cross-veins :—

Nature of ore contained in the lodes.	Lodes intersected but not heaved.	Lodes heaved towards the			
		Right hand.	Left hand.	Greater angle.	Smaller angle.
Tin ore	0·18	0·56	0·26	0·52	0·30
Tin and copper ores . .	0·37	0·44	0·19	0·56	0·07
Copper ore	0·18	0·52	0·30	0·74	0·08

The mean distance to which lodes of more than two feet in width are heaved by cross-veins more than one foot wide is . . . . 28·3 feet.

The mean distance to which lodes of less than two feet in width are heaved by cross-veins more than one foot wide is . . . . 16·1 feet.

The mean distance to which lodes of more than two feet in width are heaved by cross-veins less than one foot wide is . . . . 17·0 feet.

The mean distance to which lodes of less than two feet in width are heaved by cross-veins less than one foot wide is . . . . 4·8 feet.

Henwood states that there is at least one instance on record of a lode and a cross-vein alternately intersecting one another at different depths in the same mine.

Elvans traverse the same districts as the lodes, and owing to various differences of direction and dip are frequently intersected by them. The cross-veins cut through elvans and lodes alike, but while they heave hundreds of the latter they displace scarcely a dozen of

[1] The direction of a heave is generally indicated by *right* and *left*, because the same expression serves equally well when the dislocation is approached from either side.

the elvans intermixed with them and through which they also pass.

Thermal springs of saline waters have at different times been met with in some of the deeper workings in the neighbourhood of Camborne. Among the mines in which such springs have been observed are those of North Roskear, North Crofty, Huel Clifford, and Huel Seton. The waters issuing from the first two of these localities do not appear to have been subjected to chemical analysis, but that from Huel Clifford was analyzed in 1868 by Dr. W. A. Miller.[1]

This water issued at a temperature of 125° F., and at the rate of 150 gallons per minute, in the 230-fathom level; or at a depth of 1,320 feet below the sea. Its specific gravity was 1·007, and the saline constituents were found by evaporation to amount to 646·1 grains per imperial gallon, consisting of:—

Chloride of lithium	26 05
Chloride of potassium with a little chloride of cæsium	14·84
Chloride of sodium	363 61
Chloride of magnesium	8·86
Chloride of calcium	216·17
Sulphate of calcium	12·27
Silica	3·65
Oxides of iron, aluminium, and manganese	traces
	645·45

The workings at Huel Seton have been entirely confined to the killas or clay slate. In 1872 saline waters issued at the rate of 50 gallons per minute, and at a temperature of 92° F., from the eastern fore-breast of the 160-fathom level, or at a depth of about 780 feet below the sea. At this place the lode is not well defined, and had been driven upon until a cross-vein was intersected, from which the water issued. A short distance from this point an elvan course, forty feet in width, is traversed by the same vein. An analysis of this water afforded me results which may be tabulated as follows; although, as the state of combination of the various substances present cannot be positively determined, the system of grouping adopted may be regarded as to some extent arbitrary.[2]

[1] *Report of the Thirty-fourth Meeting of the British Association*, 1864, p. 35.
[2] J. Arthur Phillips, "On the Composition and Origin of the Waters of a Salt Spring in Huel Seton Mine," *Philosophical Magazine*, Fourth Series, vol. xlvi. 1873, p. 26.

The solid matter amounted to 1005·61 grains per gallon, or 14·3658 grammes per litre.

	Grains per gallon.	Grammes per litre.
Calcium carbonate	6·45	·0921
Iron ,,	·31	·0045
Manganese ,,	trace	trace
Calcium sulphate	2·12	·0303
Cupric chloride	trace	trace
Calcium ,,	473·88	6·7697
Magnesium ,,	11·98	·1712
Aluminium ,,	63·02	·9003
Potassium ,,	6·43	·0919
Cæsium ,,	trace	trace
Sodium ,,	409·09	5·8442
Lithium ,,	34·22	·4888
Potassium bromide	trace	trace
Potassium silicate (K_2SiO_3)	4·85	·0693
Ammonia	trace	trace
Nitric acid	trace	trace
Total found by addition	1012·35	14·4623
Total found directly[1]	1005·61	14·3658
Free carbonic acid	2·61	·0373

These waters are remarkable for the large amount of lithium which they contain, but both Huel Clifford and Huel Seton Mines are now abandoned, and the springs consequently submerged. Minute quantities of the heavy metals, other than copper, were not sought after.

The mining districts of Cornwall are separable into two great divisions, that of the West and that of the East; the former lying to the west of Truro, and the latter to the east of that city. From the Land's End a metalliferous country extends almost without interruption to the parish of Kea near Truro; here a break occurs until we approach the neighbourhood of St. Austell, where another metalliferous area commences and extends in an irregular and scattered manner into Devonshire. These divisions are of very unequal extent, the western being about thirty-six miles in length with a width from sea to sea varying from six to fourteen miles, while the eastern extends for a length of nearly forty-five miles with an average width of about twenty miles. The area of the eastern region thus exceeds that of the western in

[1] The difference between the amount of total solid contents, as found directly, and that obtained by the addition of constituents, is doubtless to some extent due to the partial decomposition of aluminium and magnesium chlorides during the drying of the residue.

the proportion of two and a half to one; its annual production of the metals is, nevertheless, so greatly inferior that, in value, they amount to less than one-fifth of that of the ores raised in the other division. The principal geological features of the county of Cornwall are, in their broader outlines, indicated in the sketch map forming the frontispiece to this volume.

The mining regions of this county have been divided by Henwood into twelve distinct districts, while Mr. H. C. Salmon[1] subsequently extended this number to twenty; for the purposes of the present work it will, however, be found more convenient to adopt the classification of Mr. Robert Hunt, Keeper of Mining Records, who in his returns grouped the whole of these districts into four large divisions:—

Western Division.	All those parts of the county west of a line drawn from Marazion to Hayle.
West Central Division.	That portion of Cornwall west of a line drawn from the Dodman Point to Padstow, and east of Marazion and Hayle.
East Central Division.	That part of the county lying west of a straight line drawn from Looe through Liskeard to the boundary of the county, and east of the Dodman and Padstow.
Eastern Division.	This division is bounded on the west by a line drawn from Looe through Liskeard to the boundary of the county, and extends eastward to the River Tamar.

Western Division.—The more important mines of this division of the county are situated in the vicinity of the towns of St. Just and St. Ives. In the neighbourhood of the former the principal mines are comprised within an area six miles in length and three in breadth, about a mile south of Cape Cornwall, forming at this point the extreme western limit of the county, and bounded by the Atlantic Ocean. They are, for the most part, situated in the parish of St. Just, and have long been celebrated from being perched on the sides of perpendicular cliffs, and from being excavated for long distances under the bed of the sea. The country inland is composed entirely of granite; but nearly parallel with the coast and coinciding with the metalliferous ground, this rock forms a junction with clay slate, largely and confusedly intermixed with foliated hornblendic rocks. The older workings, which are of very remote date

[1] *Mining and Smelting Mag.*, vol. v., 1864, p. 260.

were entirely confined to the granite, which is exclusively productive of tin ; but more recently the slates and their associated hornblendic rocks have also produced large quantities of copper ores. Some lodes are exclusively productive of tin ore in the granite and of copper ores in the slates ; Henwood states that at Botallack one of the lodes was found to pass three times from granite to slate, and in each case, to contain tin ore only in the former, and copper ores only in the latter rock. In this neighbourhood, the intersections of the different veins by one another are sometimes attended with complicated and somewhat obscure phenomena. In a few cases the heaves are regular, but they are generally far from being so, and not unfrequently a lode which has continued rich up to its contact with a cross-vein has never been discovered on the other side. As is the case in other localities, the lodes of St. Just are not productive throughout their whole extent, and when poor they are usually small; poverty appearing to be often accompanied by a diminution of size. The containing rock, which is everywhere in this neighbourhood very hard, often becomes still harder when impoverishment takes place. In all the veins of this part of Cornwall the shoots of ore dip from the granite, or if they occur in that rock their direction is towards the slate. The direction of the lodes, and this general disposition of the ores, have had the effect of directing many of the workings towards the sea, and several of the mines are wrought to some extent beneath the bed of the Atlantic. At Little Bounds, Botallack, and Huel Cock the miners have been tempted to follow the ore upwards to the sea, but the openings made being fortunately small and the rock hard, a covering of wood and cement in the two former cases, and a plug of wood in the latter were sufficient to exclude the water and to secure the workings from inundation. The extent to which the excavations of some of the mines in the St. Just district have been prosecuted under the ocean, will be understood when it is stated that the diagonal shaft on the Crowns Lode at Botallack has a total length of 345 fathoms for the most part beneath the sea, passes through a very hard hornblendic rock at an inclination of $32\frac{1}{2}°$ from the horizon, and occupied four years in sinking.

Botallack was worked as a tin mine, under a perpetual grant from the Boscawen family, from 1721 to 1735, when the sett was relinquished. Subsequently to this the mine was again opened, and in 1816 was the richest in the county. It was afterwards worked as a copper mine, but in 1844 was again about to be abandoned; a rich copper lode was, however, discovered at this time, and in the following year the undertaking had again become prosperous.

The production of tin and copper ores at Botallack during thirty years, divided into decades, together with the value of the yield of each several ten years, is given below.

	Tin Ore.		Copper Ores.	
	Tons.	£	Tons.	£
Ten years to the end of 1861	1,495	112,331	7,438	85,984
,, ,, 1871	4,020	265,652	3,116	24,481
,, ,, 1881	3,868	190,704	1,869	16,752

In these mines, as well as at Huel Edward and at Levant, the dashing of the waves against the cliffs, and the grating of the shingle on the bottom, can be heard even in moderate weather. The quantity of underground water throughout the neighbourhood is extremely small, and notwithstanding that it is somewhat salt in the workings extending beneath the sea, the amount is not perceptibly greater than in mines situated at some distance inland.

The St. Ives mines, on the opposite side of the Land's-End mass of granite, occupy a position somewhat analogous to those of St. Just. The granite forms a similar junction with the clay slate or killas of St. Ives Bay, which is in the same way much intermixed with various hornblendic rocks. The lodes, which occur in both granite and slate, are in the former exclusively productive of tin; while in the latter, as well as in the hornblendic rocks, copper ores often predominate. Little or no copper is, however, at present, raised in this neighbourhood, and its production of tin is much less important than formerly, since many of the most extensive mines, having ceased to yield remunerative returns, are no longer in active operation. The extreme length of this mining field in a north-westerly direction skirting the granite, is about four miles, and its greatest width nearly three miles. It includes the larger proportion of the three parishes of St. Ives, Lelant, and Towednack, and possesses some marked peculiarities; one of the most notable being the presence of carbonas or extensive impregnations of tin ore extending from some of the lodes into the neighbouring granite. Large and rich masses of tin ore have also, from time to time, been met with surrounded on all sides by hard granite, and apparently unconnected with any lode or vein.

The direction of the lodes is rather to the N. of E. and S. of W., while that of the cross-courses is within a few degrees of N. and S., having approximately the strike of the joints of the adjoining rock. The veins worked in granite usually produce tin ore, while those in slate, although, sometimes also yielding tin more frequently afford copper ores. Tin has, however, always been the staple product of the mines in this neighbourhood.

The most remarkable mine in the western division of Cornwall is, perhaps, St. Ives Consols, which is situated in granite, although at only a short distance from the junction of that rock with hornblendic schists and quartz-diabase, which appear immediately to the east, where they overlie the granite as seen in some of the

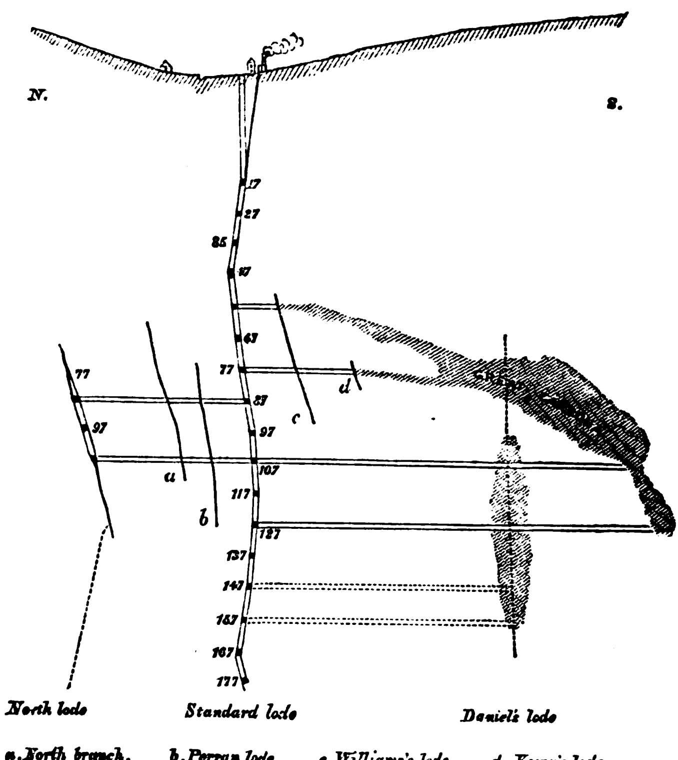

FIG. 44.—Standard Lode and Carbonas, St. Ives Consols; after H. C. Salmon.[1]

eastern shafts. It lies immediately west of the town, and the principal lode traverses the bottom of a valley through which flows the stream falling into the sea at St. Ives. The vein which passes through the valley above referred to, is known as the Standard Lode, and is nearly vertical, its bearing being a little N. of E. and S. of W. The accompanying transverse section of this lode, Fig. 44, shows how

[1] *Mining and Smelting Magazine*, vol. iii. p. 140.

slightly its course downwards varies from the perpendicular, as well as its connection with the various carbonas.

The Standard Lode has been worked to a depth of 177 fathoms below the adit level, which is itself twenty fathoms from the surface, thus making the total depth of the mine nearly 200 fathoms. In the lower levels this lode is hard and unproductive, so that but little has been done at that depth, and the workings in the bottom have been many years abandoned. The Standard has, in the aggregate, been a very productive lode, although it is nowhere large, and probably does not average more than four and a half feet in width, although varying considerably in this respect. It is chiefly composed of quartz, chlorite, decomposed granitic matter, and schorl; the latter being plentiful where tin is abundant.

The most striking feature of this mine is, however, the extraordinary deposits of tin ore which have been found south of the Standard Lode and to which the name of "carbonas" has been locally given. Fig. 44 affords some idea of the way in which these carbonas branch off from the Standard Lode. One of them, called Lawry's Carbona, shoots off at the 57-fathom level, dipping rapidly as it goes south, and forming stanniferous flats of various dimensions which have been worked by a series of irregular caverns, very unlike the openings resulting from ordinary mining operations. Another, uniting with the Great Carbona, goes off at the 77-fathom level; and at about forty fathoms south of the Standard, the level driven on the western cross-course intersects what is called Kemp's Lode, bearing nearly north and south, which is itself apparently part of a carbona. This so-called lode was driven upon for some distance until it came in contact with Noal's Lode, and with flats and droppers coming down from Lawry's Carbona at its junction with which the whole opened out into one of the most remarkable deposits of tin ore ever discovered in Cornwall.

Many of the workings are in the form of enormous caverns from 60 to 75 feet in height and equally wide. The workings on the Great Carbona were destroyed many years ago by an accidental fire which consumed the supporting timbers, and after burning for more than six weeks, at the end of that time, left the whole in a state of utter ruin. All the carbonas occur south of the Standard Lode, and wherever they are productive they are characterized by the presence of large quantities of schorl.

The workings on Daniel's Lode are remarkable for their immense width, which often reaches upwards of forty feet, although when unproductive it is barely traceable. This deposit although generally called a lode evidently belongs to a class of impregnations much resembling those known as carbonas. St. Ives Consols is now worked above the adit level only, and a large portion of its produce is obtained from the treatment of "halvans;"[1] in 1881 it yielded 52 tons 12 cwts. 2 qrs. 23 lbs. of concentrated tin ore (black tin) of the value of £2,755.

The total production of the mines of the western division of Cornwall during the same year was, according to the statistics published by the Mining Record Office, as follows:—

	Weight.			Value.		
	Tons	cwts.	qrs.	£	s.	d.
Black Tin	1,362	8	2	73,395	19	8
Copper Ore	1,190	1	0	8,127	13	9
Totals .	2,552	9	2	81,523	13	5

West Central Division.—This extends over a much larger area than the western division, and comprehends a great proportion of the most important mines in the county.

Those near Marazion are situated in a basin of killas stretching from that town eastward along the coast of Mount's Bay for a distance of upwards of four miles to the mass of granite culminating at Tregoning Hill. Its width from the sea inland is about three miles, comprising the parishes of St. Hilary and Perranzabuloe, with parts of Breage and Germoe. The mines distributed over this district have, in the aggregate, yielded large quantities of copper and tin, but principally the former, which appears to generally occur in the vicinity of elvan courses; the district has not, however, been characterized by any very deep or permanent mines.

The mines of the Breage and Sithney district occupy a killas basin lying between the granite of the Tregoning and Godolphin Hills and the larger granitic mass of the Wendron range. It is very restricted in length, since it skirts the smaller mass of granite from north to south without extending any considerable distance eastward. It includes the larger portions of the parishes of Breage and Germoe with a part of Sithney, and is almost exclusively a tin-producing area, having yielded some of the richest and deepest deposits of tin ore which have been found in Cornwall. Although this district consists principally of killas, its granite has also yielded tin.

In the parishes of Gwinear, Crowan, Phillack, and St. Erth are

[1] Refuse ore thrown aside as not being, at the time, sufficiently rich to pay the expenses of treatment.

various copper mines which are usually productive in the neighbourhood of elvan courses. The country rock is generally slate, varying in colour from blue to pale buff, but sometimes made up of alternate blue and white laminæ. At Relistian the slate contains numerous spheroidal concretions, some of which are apparently composed of slaty material, while others are entirely quartzose. In the neighbouring mine of Herland, at a depth of about 110 fathoms, numerous nodular masses of granite have been found enclosed in the killas. These, which vary from half an inch to three feet in diameter, are composed of a fine-grained granite, the felspar of which is much decomposed. They are entirely surrounded by clay slate, and have no apparent connection with one another. Elvan courses and dykes of "greenstone" are numerous in this neighbourhood, and the elvan often contains a large quantity of schorl. It is sometimes stanniferous, and has in a few localities been worked for the tin it contains. At Parbola the elvan is everywhere traversed by minute strings of tin ore. A striking characteristic of the lodes in this part of Cornwall, which is very unusual in other parts of the county, is that they, as well as the contiguous rocks, contain large quantities of the globular concretions already noticed. Copper pyrites and copper glance are the most abundant minerals, but tin ore is, to some extent, found in a large number of the mines.

The mining districts of Wendron, Camborne, Redruth, and Gwennap are in connection with the great granite range of Carn Menelez and the two smaller associated masses of Carn Brea and Carn Marth. The Wendron mines are situated in the granite of the Carn Menelez range, and are principally in the parish of Wendron, although they also extend into the parishes of Sithney, Crowan, and Constantine. This is a wild moorland district, and although producing considerable quantities of tin ore it does not possess any very characteristic mining features.

Some of the mines of the Camborne district are at the present time the richest in Cornwall, and are comprised within those portions of the parishes of Camborne and Illogan bounded on the east by the valley which divides Illogan from Redruth; on the south by a line passing through the ridges of Carn Brea, Carnarthen Carn, and Camborne Beacon; on the west by a line drawn from Camborne Beacon to about half a mile north of Camborne Church; and on the north by the highway from Camborne to Redruth. The prevailing rock is granite, which rises on the south into an elevated range of hills, whose northern slope is covered by killas traversed by various elvans, lodes, and cross-courses. The mines of this neighbourhood are the deepest in Cornwall, and are remarkable for being at great depths as rich for tin as they were formerly for copper in the shallower levels.

The following table, giving the annual production of copper and tin ores at Dolcoath Mine from 1849 to 1881 inclusive, indicates the very gradual way in which this undertaking has become transformed from a copper mine to one producing tin ores only. The shallower levels of this mine were driven exclusively in killas, while the deeper workings are entirely in granite. In killas the lodes produced large quantities of copper ore, but upon entering the granite this ore became rapidly replaced by cassiterite. At the present time Dolcoath is the deepest mine in Cornwall, the engine shaft having reached a depth of 400 fathoms.

Year.	Copper Ore.			Tin Ore.	
	Tons.	Value.	Produce.	Tons.	Value.
		£			£
1850	1,115	4,909	$6\frac{1}{2}$	—	—
1851	801	3,266	$6\frac{7}{8}$	—	—
1852	832	3,344	$5\frac{1}{8}$	—	—
1853	1,040	4,920	5	360	22,680
1854	992	4,313	$4\frac{1}{2}$	363	25,261
1855	711	2,634	4	352	23,169
1856	617	1,998	$3\frac{7}{8}$	416	30,727
1857	566	2,430	$4\frac{1}{2}$	544	42,880
1858	598	3,085	$6\frac{1}{16}$	635	41,859
1859	757	3,531	$5\frac{1}{8}$	724	53,506
1860	712	2,426	4	805	64,974
1861	417	1,589	$4\frac{1}{2}$	864	63,862
1862	508	2,357	$5\frac{7}{8}$	986	66,220
1863	636	3,029	$6\frac{1}{4}$	1,026	69,741
1864	621	3,289	$6\frac{1}{4}$	1,030	66,959
1865	607	3,510	$7\frac{5}{8}$	944	53,238
1866	688	3,512	$7\frac{1}{2}$	919	46,120
1867	267	1,068	$5\frac{1}{8}$	848	46,169
1868	153	863	$8\frac{1}{8}$	984	55,847
1869	153	648	$6\frac{7}{8}$	813	59,694
1870	57	224	—	1,034	78,601
1871	86	326	$6\frac{1}{2}$	1,070	95,373
1872	50	234	—	1,269	113,114
1873	15	72	—	1,045	82,501
1874	73	410	—	1,121	65,558
1875	—	—	—	1,241	65,346
1876	41	163	—	1,263	55,825
1877	30	112	—	1,404	59,180
1878	14	28	—	1,539	55,902
1879	—	—	—	1,780	71,216
1880	—	—	—	1,736	93,702
1881	—	—	—	1,816	102,039

PRODUCTION FROM 1852 TO 1881.

	Copper Ore. Tons	£	Tin Ore. Tons.	£
Nine years ending 1861 .	6,410	26,926	5,063	368,918
Ten ,, 1871 .	3,776	18,826	9,654	637,962
,, ,, 1881 .	223	1,019	14,214	764,383

During thirty years, namely, from 1851 to 1881, East Pool Mine, near Camborne, produced ores of the following weights and values:—

	Copper Ore. Tons.	£	Tin Ore. Tons.	£
Ten years to end of 1861 .	20,208	100.417	416	25,895
,, ,, 1871 .	22,444	72,333	2,174	129,961
,, ,, 1881 .	18,603	55,054	6,161	283,806

Among the most remarkable phenomena exhibited in this part of Cornwall are the alternations and mixtures of granite and slate which occur near the line of junction of the two rocks in the mines of Cook's Kitchen, Tincroft, Dolcoath, and Carn Brea. In the southern part of Cook's Kitchen a friable, coarse-grained granite appears at the surface and continues downwards to a depth of about thirteen fathoms, where it is succeeded by a bed of slate which reaches a depth of thirty-nine fathoms. The upper portion of this mass of slate is of a deep blue colour, and has a distinctly crystalline structure, showing, somewhat obscurely, evidences of foliation. Lower down it becomes gradually more micaceous, and shows well-defined planes of cleavage. Veins of granite penetrate both the upper and lower surfaces of the slate. Below this there is a bed of fine-grained granite ten fathoms in thickness, containing a large amount of schorl, beneath which masses of granite and of slate alternate in a very irregular way. The transitions from one to the other are sometimes gradual, while at others they are very abrupt, and in nearly all cases the slates are traversed by veins of granite.

At Tincroft the granite goes down to a depth of twenty-six fathoms from the surface, at which point the slate makes its appearance, and continues without interruption to a depth of eighty-four fathoms, where at length the main body of the granite appears.

At Dolcoath a large mass of hard slaty rock has recently (1882) been met with in the 352-fathom level, east of the new eastern shaft, at a total depth of 380 fathoms from the surface. This slate is included in the granite 240 fathoms below the point where that rock was first cut into by the workings, and 310 fathoms below the sea level. This enclosure closely resembles the ordinary killas of the district, and on comparing thin sections of the two, as seen under the microscope, their identity becomes at once apparent.

The Redruth and Gwennap district immediately adjoins, on the east, that of Camborne, so that an arbitrary line only can be drawn between them. The district includes the parishes of Redruth and Gwennap, with parts of Kenwyn, Kea, and St. Agnes. It is essentially a copper-bearing neighbourhood, and formerly produced very large quantities of that metal, but for many years its productiveness has gradually fallen off, and many of its once rich copper mines may now be regarded as exhausted. The Great Consolidated Mines of Gwennap in the course of twenty-one years (1819—1840) sold ores to the value of £2,254,485, of which £480,156 was divided as profit. Some important mines were formerly worked along the north coast of the county in the parish of St. Agnes, and in the western portion of Perranzabuloe. They have been largely productive of tin and copper, the ores of both metals appearing to be most frequently met with in the vicinity of elvans.

The Great County Adit of Cornwall empties itself into the Carnon stream, which falls into Restronguet Creek, and extends to many of the mines in the vicinity of Redruth. Its greatest depth from the surface is seventy fathoms, its total length, including branches, thirty miles, and the level of its mouth above high water thirty-nine feet. It is at present of comparatively little importance, as many of the principal mines in connection with it are worked out and abandoned. Many years ago it drained an area of 5,550 acres, and discharged on an average 1,450 cubic feet of water per minute. A little copper is sometimes obtained from the waters of this adit by precipitation by scrap-iron.

Numerous lead veins, running in almost every direction, occur in a district lying north of Truro and comprising a large portion of the parishes of Perranzabuloe, Newlyn, Cubert and Crantock. This region has produced one or two rich lead mines, and several moderately productive ones. For a long time East Huel Rose was the most productive lead mine of this district, but eventually it was submerged by an accidental influx of surface water during a flood. It subsequently remained unworked for many years, but has quite recently been again set in operation. Its production from 1844 to the end of 1861 was as follows :—

Year.	Lead Ore.	Lead.	Silver.
	Tons.	Tons.	Oz.
1845	7,883	4,729	
1846	5,191	3,114	
1847	6,424	3,854	
1848	5,333	3,191	
1849	4,759	2,856	
1850	4,203	2,524	
1851	3,193	2,234	
1852	2,381	1,607	43,000
1853	1,357	925	27,499
1854	1,215	828	24,629
1855	2,343	1,510	46,760
1856	2,691	1,776	53,280
1857	1,199	791	23,739
1858	726	416	10,400
1859	728	386	13,090
1860	607	322	10,948
1861	147	66	2,376

This mine sold copper ore in the following years :—

	Tons.		£
1850	67	Value	734
1851	93	„	789

West Chiverton was another important mine in this neighbourhood, and commenced selling lead ores in 1859; the following were its most productive years :—

Year.	Ore.	Lead.	Silver.
	Tons.	Tons.	Oz.
1866	3,166	1,970	66,950
1867	4,082	3,061	130,624
1868	4,516	3,387	144,512
1869	4,707	3,529	150,504
1870	4,777	3,582	161,190

In 1881 its production only amounted to 177 tons 3 cwts. of lead ore, containing 1,747 oz. silver, and having an aggregate value of £2,120.

In this section of the county there are also lead veins at Swanpool and Pennance, near Falmouth, and others near Porthleven, south-west of Helston.

Park of Mines is situated three miles south of St. Columb on the west side of the road leading from that town to Truro, and has at various times yielded a considerable amount of tin ore from deposits of a somewhat unusual character.[1] The enclosing rock is killas, which may here be defined as a grey, buff, or white indurated schist, dipping at an inclination varying from 30° to 80° in a general northerly direction. The north-western corner of the great granite range which lies to the north of St. Austell extends to within three-quarters of a mile of this mine. Numerous small veins, generally dipping east, traverse the killas from north to south, and

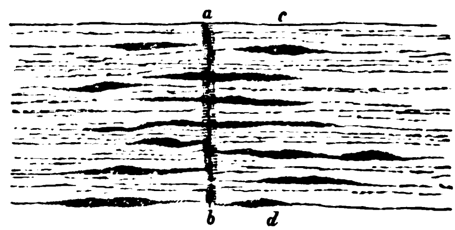

FIG. 45.—Horizontal section, Park of Mines.

usually vary in width from the thickness of a common table-knife to a quarter of an inch. These are mainly composed of quartz, but the killas for a distance of from half an inch to two inches on each side has been blackened and hardened by an impregnation of schorl.

The tinstone of the Park of Mines has apparently been derived from lateral offshoots of the north and south veins, as in the

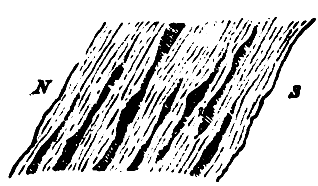

FIG. 46.—Vertical section, Park of Mines.

proximity of these strings lenticular masses of tin ore occur interposed between the bedding planes of the killas.

The mode of occurrence of the tinstone at Park of Mines will be best understood by referring to the above diagrams. Fig. 45 represents, in horizontal section, a north and south vein, *a b*, as seen at the twenty-fathom level, with layers of tinstone which rarely extend for a distance of more than six feet on each side of it. Fig. 46 is a vertical section on the line *c d*, showing the beds of

[1] C. Le Neve Foster, *Miners' Association of Cornwall and Devon*, 1875, p. 22.

killas dipping north at an angle of 70°, with interposed lenticular masses of tin ore. The stanniferous zone in this particular case extends about seven fathoms from north to south, and ten fathoms along the line of dip. The lenticules of tin ore do not usually exceed two inches in thickness at their widest part; the whole mass of killas and tinstone being consequently worked away together and sent to the surface to be stamped and dressed. Occasionally the thickness of tinstone reaches nearly a foot, the only minerals associated with it being schorl, quartz, and kaolin. The killas near the boundary of the stanniferous layers is usually stained by oxide of iron, and consequently red killas is regarded by the miners as a favourable indication of their near approach to a deposit of tinstone. The workings of this mine, which extend over an area of about an acre only, have been prosecuted to a depth of about forty-five fathoms. In 1874 the Park of Mines yielded 231 tons of black tin.

The production of ores from mines in the West Central Division of Cornwall was during the year 1881 as follows:—

	Weight.			Value.		
	Tons	cwts.	qrs.	£	s.	d.
Black tin	9,088	16	0	504,376	3	11
Copper ore	11,243	13	0	39,288	1	5
Lead "	297	0	1	3,268	10	0
Zinc "	7,792	17	3	23,565	2	0
Silver "	1	12	2	175	0	0
Iron "	3,257	0	0	1,869	10	0
Iron pyrites	957	3	0	467	3	6
Wolfram	49	5	0	495	8	0
Totals . . .	32,687	7	2	573,504	18	10

East Central Division.—The St. Austell mining district comprehends the whole of the St. Stephens and Hensbarrow range of granite, together with a band of killas surrounding it on all sides, averaging in width about three miles. On the south this district is bounded by the sea, extending from the Black Head to Tywardreath, on the west to St. Denis, on the north nearly to Bodmin, and on the east to Lostwithiel. It comprises parts of the parishes of St. Ewe, St. Mewan, St. Austell, St. Blazey, Tywardreath, Lanlivery, Lanivet, Luxulyan, Roche, St. Denis, and St. Stephens. The mass of granite, which is here very large, exhibits the same characteristics as those of the western districts, and frequently contains much schorl. This neighbourhood supplies nearly the whole of the china clay and china stone sent from Cornwall to the Potteries, or which is exported to other countries. This district was formerly very productive for both tin and copper, but at the present time all the principal copper mines have been suspended, and Huel Eliza, a mile and a half east of St. Austell, is now the only rich tin mine working in this part of the county. Small quantities of tin are, however, still annually obtained from the granite in what is known as the St. Austell-Moor district. The once celebrated tin mines of Polgooth and Hewas were worked in the belt of killas a little south-west of the town of St. Austell, while in the same rock, to the east, were the tin mines of Bucklers and the copper mines of Pembroke, East Crinnis, Mount, and Fowey Consols, all of which have long since ceased working upon an extensive scale. The well-known tin mine of Beam, situated in the granite, is no longer in operation, and the great open cutting at Carclaze is worked chiefly for china clay.

The granite throughout this district is traversed by innumerable schorlaceous veins, which, although generally very small, almost invariably contain a certain proportion of tin oxide. The tin ore is, however, seldom confined exclusively to such veins, but is generally disseminated throughout the substance of the contiguous rock, into which, although the line of separation is usually distinguishable, the veins frequently pass by imperceptible gradations. The killas of this district is fine-grained, with a silky lustre, and schistose structure. Its colour is usually blue, varying considerably in intensity, while its prevailing dip is towards the south-east. In many places it abounds with beds and veins of white quartz. Dykes and irregular patches of an altered doleritic rock, now represented by various greenstones, penetrate the slates of many parts of this district. Elvan occurs in the sea-cliff at Polruddan, and extends through Hewas Mine to beyond Tolgarrick, in the parish of St. Stephens. At Stennagwyn, in that parish, there is a remarkable impregnation of the granite with tin ore, of which a portion is in the form of tin sulphide or *stannite*. A small quantity of black tin has on various occasions been obtained from this locality, but the whole of the stannite is lost during the operation of dressing.

The direction of the lodes in this neighbourhood is usually a few degrees S. of W., but there are others which bear nearly S.E. and N.W., thus closely approximating to the direction of the counter lodes in the western parts of Cornwall. There are but few cross-courses or cross-flucans in the district; but at Polgooth a flucan heaves the lodes and elvan a distance of thirty fathoms, and in the same mine the St. Martins and Screeds Lodes both appear to be displaced by an elvan course, a phenomenon which is believed to be without parallel in the mines of the county.

At Restormel, near Lostwithiel, there is a large iron lode bearing about 15° W. of N., and dipping E. 75°. It varies from two to four fathoms in width, and is generally divided into two branches by a band of slate. Workings have been extended on the course of this lode for a distance of nearly two miles, but their depth is generally inconsiderable. The chief produce of this vein is hæmatite, with a little black oxide of manganese, while göthite, associated with quartz, occurs as crystals lining numerous druses disseminated throughout the veinstone. The shoots of ore met with in the neighbourhood of St. Austell usually dip from the granite.

Fifty years ago among the most prosperous and well-managed copper mines in the killas of this district were those of Fowey Consols, situated in the parish of Tywardreath. The lodes in this locality are much contorted in length and depth, and are remarkable for the number of junctions they make with one another in their downward course. The enclosing killas, which is of a pale blue colour, alternates with bands of felsite, while the veinstone is principally composed of milk-white quartz, often enclosing angular fragments of the country rock. Iron pyrites and spathose iron ore are frequent constituents of these lodes; the other minerals present being various ores of copper, with bismuthine, the latter occurring in larger quantities in this mine than in any other locality in Cornwall. The extent of these mines is very considerable, since some of the lodes are believed to run through the sett for a distance of above a mile. From August 1815 to the end of the year 1841, these mines returned 234,486 tons of copper ore, which sold for £1,442,683, and out of this amount the profit paid to the shareholders was £179,995, leaving a large reserve fund not divided. The estimated value of plant and machinery was, in the latter year, about £55,000, but shortly after this date the annual produce gradually fell off, and the mines were finally abandoned in 1868. The year of their greatest production was 1838, when they yielded 15,254 tons of copper ore, produce $9\frac{0}{8}$, value £85,434.

This region once afforded a larger supply of stream tin than any other part of the county; but the more extensive stream-works, such as the Happy Union at Pentewan, Huel Virgin in the St. Austell Valley, and those in the vicinity of the Jamaica Inn, being all exhausted, a comparatively small quantity of this class of tinstone is now obtained from the district.

The tin streams of Cornwall have been long known to afford occasional specimens of gold, but not in sufficient quantities to make its collection a matter of any importance.[1]

Various lodes yielding small quantities of lead and copper ores have, from time to time, been, to some extent, explored in the tract of country extending along the north coast from St. Columb to beyond Camelford; but although small bunches of ore have occasionally been found, no adequate results have yet been obtained for the money expended.

The total production of the mines of the East Central Division of Cornwall during the year 1881 was, according to published statistics, as follows:—

	Weight.			Value.		
	Tons	cwts.	qrs.	£	s.	d.
Black tin	658	15	3	38,566	16	0
Copper ore	134	8	0	581	7	3
Silver „	4	6	1	183	7	0
Iron „	4,203	0	0	2,572	1	0
Totals .	5,000	10	0	41,903	11	3

Eastern Division.—The mines of the Caradon district are chiefly included in the parishes of St. Cleer and Linkinhorne, and are situated in a granitic area forming, for the most part, the southern border of the Bodmin-Moor mass of granite, but including also its southern and south-eastern junction with the killas. This formation is here much intermixed with hornblendic rocks, while both it and the granite are occasionally traversed by courses of elvan. In addition to the slaty rock thus skirting the granite, a tract of slate nearly a mile in length and having somewhat less than half that width, a little to the south-east of the Cheesewring, is represented as being completely surrounded by granite. That this comparatively small patch of killas is, to a very large extent, encircled by granite, appears to be certain; but that it is completely severed from the great body of sedimentary rocks lying to the east has never been conclusively proved. Within the boundaries assigned to this area of killas the hanging wall of the Phœnix Lode, to a depth of thirty-five fathoms from the surface, consists of slate, while

[1] In his *Survey of Cornwall*, 1602, Richard Carew says, "Tynners doe also find little hoppes of Gold amongst their Owre, which they keepe in quils, and sell to the Goldsmithes oftentimes with little better gaine than *Glaucus* exchange."—Book i. p. 7.

the foot wall is wholly of granite; but at all greater depths both walls are composed of granite. The shallower parts of various other lodes in this immediate neighbourhood are also bounded by slate on their south side and by granite on the north; the same is the case at Sharp Tor, north of Phœnix. At Marke Valley, three quarters of a mile to the south-east, the lode, which dips towards the north, has slate as its hanging wall to a depth of thirty-six fathoms, while the foot wall is of granite; but at all greater depths the walls on both sides are of granite. The slate which forms the hanging wall of the Phœnix Lode, to a depth of thirty-six fathoms, is very quartzose, but contains flakes of mica, with a few fragments of felspar, and occasional needles of schorl. Its colour is pink, buff, or light grey, but it is sometimes mottled with spots of crimson or of brick red; it is often coarse-grained, and is occasionally much contorted.

The outcrops of the lodes on the southern slope of the granitic range at West Caradon and South Caradon, consist of soft pale-brown or reddish-brown gossan, with friable quartz, decomposed granite, chlorite, and a little fluor spar. Where the structure is cellular, nests of clay, black oxide of copper, and malachite often occur, as well as small patches of iron pyrites, mispickel, and various ores of copper, together with cuprite, and small plates and ramifications of native metal. In the deeper portions of the same veins, quartz, felspar, and chlorite, with occasional masses of granite, are still the chief constituents; but brown iron ore, although sometimes present in small quantities, is less plentiful, while fluor spar becomes more abundant. At the same time the copper glance, cuprite, malachite, and black oxide of copper gradually disappear in depth, while the quantities of fluor spar and copper pyrites increase. These lodes contain no appreciable amount of tin ore. At Stowes, Phœnix, South Phœnix, Dunsley Phœnix, and Marke Valley, the lodes have, besides ores of copper, afforded tin ore, but contain no fluor spar; those of the Caradon Mines, on the contrary, have yielded large quantities of copper ore, and contain much fluor spar, but give little or no tin.

Several of the principal lodes in this district afford abundant evidence of the original fissure having again opened, subsequently to its becoming more or less completely filled with various crystalline minerals. The great lode at the Phœnix Mines may be cited as an example of a vein of which the constituents were deposited during two perfectly distinct periods. The first formation was stanniferous, and was attended with the production of capels; the second mainly consisted of quartz, associated with various ores of iron and copper.

One of the lodes at South Caradon has in the same way resulted from a kind of double deposition. In this case the first formation is rich in copper ores, while the second is composed chiefly of drusy quartz, with fluor spar and iron pyrites.

Three of the principal mines in the Caradon district yielded copper ores to the following amounts and values, during the several periods stated in the following table :—

					Tons.	£
South Caradon—ten years to end of				1861	41,790	429,551
,,	,,	,,		1871	60,794	491,782
,,	,,	,,		1881	57,389	361,413
West Caradon	,,	,,		1861	39,464	342,684
,,	,,	,,		1871	13,341	79,988
,,	,,	,,		1881	1,663	5,936
East Caradon	,,	,,		1871	39,091	194,926
,,	,,	,,		1881	10,425	53,494

During the year 1881 these mines made the following returns respectively :—

	tons	cwts.	£	s.	d.	Produce.
South Caradon	5,185	9	27,609	3	2	9¼
West Caradon	227	3	804	14	6	6¾
East Caradon	118	19	533	16	8	7¾

The lead veins of the neighbourhood of Liskeard are situated in the parishes of Lanreath and St. Pinnock, three and half miles S.W. of the town, and seven miles from the Caradon granite; and in the parish of Menheniot, about one and half mile S.E. of Liskeard. The latter district extending from Butterdon, near the Callington turnpike to within half a mile of Menheniot Church. The Lanreath and St. Pinnock district is a very small one, being scarcely a mile long, by one eighth of a mile in width. Its only important mine now in operation is Herodsfoot, which was the first mining work undertaken in the neighbourhood of Liskeard. The Menheniot lead district is about a mile and a half in length and half a mile in width; its principal mines being Huel Mary Ann and Huel Trelawny.

The Lanreath and St. Pinnock Mines lie a little west of the imaginary boundary line, and, therefore, belong, strictly speaking, to the East Central Division of the county; as, however, this district adjoins that of Menheniot and resembles it in many respects, it will be more convenient to describe them together.

The rocks of both these districts chiefly consist of slates, sometimes enclosing Devonian fossils, and near the surface are generally brown, drab, or dun-coloured, but at greater depths have a silky lustre and assume a deep blue or blackish hue.

At various depths in the mines of Huel Trelawny and Huel Mary Ann the ordinary killas has, lying between its planes of bedding, conformable sheets of felspathic and hornblendic rocks, which are locally known as elvans; and are usually massive, but sometimes exhibit a schistose structure. Between these and the slate there is sometimes a gradual change, but more commonly the transition from one to the other is distinct and immediate. The felspathic and hornblendic rocks of this neighbourhood occasionally contain spheroidal bodies made up of many concentric layers. This structure is not, however, entirely confined to the hornblendic and felspathic rocks, since Henwood states that at Huel Trelawny a concretion of this kind, consisting of five distinct layers of quartz and galena, was found in a siliceous slaty matrix at a depth of 55 fathoms from the surface.

In neither of these districts has more than one productive lode been discovered. That upon which the Menheniot mines have been opened takes somewhat different directions in various parts of its course, its bearing in Huel Trelawny being 5° W. of N. and E. of S., while in Huel Mary Ann its course is from 3° to 8° E. of N. and W. of S. In the Lanreath district the lode at Herodsfoot bears from 8° to 12° W. of N. and E. of S.

The lodes of this region maintain an average dip of 79°, their inclination being to the east; in thickness they vary from six inches to four feet, the average width being probably about two feet. The chief constituent of the lodes in both districts is quartz, which, near the surface, is often granular, and is mixed with ferruginous gossan, but at greater depths is generally massive and milk-white in colour. In the Menheniot Lode chalcedonic silica is sometimes associated with vitreous quartz and chalybite, while calcite occurs in the deeper levels. At Herodsfoot pearl spar is found in the joints and crevices both of the lode and of the country rock. Iron pyrites, which is usually more or less argentiferous, is a common constituent of both lodes, while small quantities of chalcopyrite and blende occur most frequently in the more quartzose portions of the veins. In addition to these minerals the lode at Herodsfoot contains bournonite and sulphide of antimony. Carbonate and phosphate of lead occur near the surface, but lower down these minerals are entirely replaced by galena. In the Menheniot Lode the ore is often associated with quartz and fluor spar; while at Herodsfoot, on the other hand, a granular quartzose veinstone, including numberless spots and patches of galena, is traversed by strings and ribs of that ore. In this, as in all other lead districts, the ores obtained from different lodes, and even from different parts of the same lode, are unequally argentiferous. The ore sold at Huel Trelawny from 1851 to 1869 afforded on an average ·001246 its weight of silver, which is equivalent to 40 oz. 13 dwt. 9 gr. per ton of 2,240 lbs.

At Huel Mary Ann the ore returned from 1851 to 1869 yielded on an average ·001435 of silver, equal to 46 oz. 17 dwt. 12 gr. per ton. In both mines there was a gradual increase in the proportion of silver from the shallower to the deeper levels. Huel Mary Ann and Huel Trelawny suspended operations in 1876.

The lead ore extracted from the northern and southern mines at Herodsfoot from 1851 to 1867 afforded on an average ·000814 of silver, equivalent to 26 oz. 11 dwt. 16 gr. per ton. The lead ores raised throughout Cornwall in 1855 contained on an average about 23 oz. of silver per ton.

The lodes of this district frequently enclose thin laminæ of slate, which usually assume the direction and dip of the enclosing veins. These fragments are often sharply defined and quite unaltered, but they are sometimes permeated by siliceous and calcareous matter, or are penetrated by strings and branches of veinstone. The leaders or metalliferous portions of the veins are sometimes separated from the country rock by a band of breccia, consisting of angular masses of slate sometimes enveloped in as many as six accretions of chalcedonic quartz. These enclosed fragments are often exceedingly small, and seldom exceed three inches in diameter; they have frequently to some extent become replaced by quartz; and thin branches of this mineral, containing either galena or iron pyrites, often intersect or interlie the laminæ. Cavities studded with botryoidal concretions of agate-like silica encrusted with crystals of quartz and sprinkled over with calcite and chalybite, occur in all parts of the siliceous cement.[1]

Towards the southern portion of Huel Mary Ann and throughout the adjoining mine of South Huel Trelawny as well as between the old and new mines at Herodsfoot, the lodes are represented by bunches and disconnected strings of veinstone, occasionally containing a few spots and bunches of ore. These usually follow

[1] Fig. 30., p. 47, shows the mode of occurrence of brecciated veinstone at Huel Mary Ann, while Fig. 27, p. 44, represents a quartzose concretion from Huelgoet of the same character as those which are found in the cementing material of the Menheniot lodes.

a joint maintaining the normal direction of the lode, but seldom affect parallel portions of neighbouring joints. Wherever the lodes are thus broken up and disturbed the country rock is disordered and traversed by numerous flucans of slaty clay.

The workings at Herodsfoot were extended, at different depths, for distances varying from thirty to forty-five fathoms through this disordered ground, before the lode, which had dwindled in the old mine, was again found in the new. At Huel Mary Ann and South Huel Trelawny still greater distances were laid open without success. The water of these mines contains large quantities of sulphate of calcium.

The Menheniot lead lode is intersected by two flucans, the most northerly of these, in Huel Trelawny, bears 10° S. of E. and dips S. about 55°; the more southerly, in Huel Mary Ann, bears about S.E. and N.W., with a dip N.E. varying from about 40° to 50°. The lode has consequently the direction of the unproductive cross-courses of other districts, while the flucans have the same bearing as the lodes of tin and copper.

According to Henwood the profits made from 1844 to 1869 were as follows:—

Huel Trelawny	£56,914
Huel Mary Ann	65,585
Herodsfoot	49,848
Total .	£172,347

At Huel Ludcott, in the parish of St. Ive, about a mile and a half N.N.E. of Huel Trelawny, the country rock is a glossy dark-blue killas, with planes of cleavage ranging nearly N.E. and S.W. and dipping from 15° to 20° S.E. Two nearly parallel lodes running about N. and S., and dipping from 80° to 86° E., have been worked, one to a depth of 80 and the other to that of 130 fathoms. The shallower parts of both veins consisted of granular quartz, gossan, and slaty clay, with, occasionally, a little iron pyrites, chalcopyrite, blende, and galena. At more considerable depths the quartz became less crystalline, and calcite made its appearance. In some places both these lodes, which vary from two to three feet in width, were rich in galena, which, on one side of the north cross-course, contained nearly twice as large a proportion of silver as on the other. Three cross-veins, all bearing E. and W., dipping S., and varying from one foot to eighteen feet in width, intersect both lodes.

The cross-veins generally consist of slaty clay, granular quartz, calc spar, chalybite, and iron pyrites; but sometimes the quartz becomes more flinty, and isolated masses of galena or small patches of copper pyrites make their appearance. Between the severed portions of the eastern lode, at depths varying from 93 to 110 fathoms, the northern cross-course enclosed crystals of galena poor in silver, occasionally detached, but sometimes embedded in masses of argentite of considerable size. Stephanite, pyrargyrite, and argentite were also met with in druses, where they were sprinkled over crystals of quartz and calcite. Crystals of galena were also often covered in the same way with crystals of silver ore, and threads of native silver traversed the veinstone as well as the galena and other ores. From this cross-course 304 tons 15 cwts. of silver ores were obtained, which sold for a little more than £22,501, making an average of £73 16*s.* 3*d.* per ton. The percentage of lead varied from 7 to 40 per cent., but the average yield of this metal was not much above 9 per cent. and the ores can, therefore, only be regarded as silver ores.

The Callington mining district may be described as an area chiefly consisting of clay slate, which includes the two smaller granite protrusions of Kit Hill and Gunnis Lake, constituting links between the two great ranges of Bodmin Moor and Dartmoor. It comprises parts of the parishes of Callington, Calstock, and Stoke Climsland, including an area of about five miles in length and nearly three in width.

The granite of Kit Hill and of Gunnis Lake is somewhat finer in grain than that of the larger masses of that rock further west, but it is frequently traversed by veins of quartz and schorl, which sometimes contain tin oxide. The slate varies considerably in different localities both in colour and in texture. At Drake Walls, where it is of a deep blue colour and has a silky lustre, several lodes have been worked, and have in the aggregate produced large quantities of tin ore, which is, however, usually associated with wolfram. The rock is often traversed by small veins of cassiterite, like those which occur in slate at Polberrow, and in granite at Carclaze and elsewhere in Central Cornwall. The direction of the lodes is generally a few degrees S. of W.; but some of them bear rather N. of W. They dip for the most part towards the north, although a few have an opposite inclination. Cross-courses are numerous, and they occasionally heave the lodes to a considerable distance. Huel Betsy and Redmoor, which are both in killas, have yielded large quantities of galena associated with chalybite. Native copper, cuprite, malachite, black copper, copper glance, copper pyrites, and sundry rare minerals, and among others uranite, have been found at Gunnis Lake.

A metalliferous bed containing quartz, chalybite, copper pyrites, and other minerals occurs at Virtuous Lady. Its course is about 20° S. of W., and its dip N., with a thickness varying from a few inches to thirty feet. The ores, which are very irregularly disseminated throughout the mass, usually occur in the quartz, but large patches are also sometimes found associated with carbonate of iron, and iron pyrites. This mine was long celebrated for its fine crystals of chalybite. Childrenite has been found at the George and Charlotte Mine, as well as at Huel Crebor, in this district.

The Callington district at the present time is of but little commercial importance as a mining area, although it was formerly much more productive. The mine now making the largest returns is Gunnis Lake Clitters, which, during the year 1881, yielded 2,520 tons of copper ore, of the value of £15,831 15*s*. 6*d*.

The production of the mines of the Eastern Division of Cornwall, during the year 1881, was as follows :—

	Weight.			Value.		
	Tons.	cwts.	qrs.	£	s.	d.
Black tin	541	13	1	29,958	8	0
Copper ore	11,941	17	0	56,390	16	10
Lead "	467	17	1	4,550	7	10
Iron pyrites	13,953	6	0	13,154	16	11
Wolfram	5	2	2	48	13	9
Totals .	26,909	16	0	104,103	3	4

In addition to the black tin produced by the mines of Cornwall during the year 1881, 957 tons 1 cwt. were obtained from streams, rivers, and foreshores, and 263 tons 19 cwts. 2 qrs. of black tin were returned as sold in the form of undressed tin-stuff. During the same year 2,774 tons of arsenious oxide (As_2O_3), worth £19,250, were produced in Cornwall from the roasting of ores containing arsenic.

Statistics Relating to the Production of Tin, Copper, and Lead Ores in Cornwall.—The period at which Cornish tin was first worked and exported has been lost in the obscurity of ages. According to Borlase, however, the production of tin in Cornwall was very inconsiderable even in the time of King John, 1199-1216. In this reign the tin farms of the county yielded no more than

100 marks per annum, and in accordance with this valuation the Bishop of Exeter received, in lieu of his tenth part, the sum of £6 13*s.* 4*d.* The tin farms of Devonshire, at the same period, yielded £100.

In 1750 the production of the Duchy of Cornwall was 18,698 blocks, equivalent to about 3,132 tons of metallic tin. In 1800, after having been in 1789 as high as 22,132 blocks, the production was 16,397 blocks, or about 2,746 tons. The production of metallic tin in the year 1838, after having been as high in 1827 as 31,744 blocks, amounted to 29,321 blocks, or about 4,911 tons.

Until the year 1854 the production of the Cornish tin mines was by the Mining Record Office grouped with that of Devon, although the yield of the latter county was relatively unimportant. The following table gives the production of tin in Cornwall from the date at which records of the yield of the two counties have been kept separate.

WEIGHT AND VALUE OF TIN ORE OBTAINED FROM CORNISH MINES FROM 1854 TO 1881.

Year.	Tons.[1]	Value of ore.	Remarks.
		£	
1854	8,447	540,608	
1855	8,627	586,636	
1856	9,214	764,762	
1857	9,688	786,228	
1858	9,905	630,328	
1859	10,059	723,370	
1860	10,225	798,209	
1861	10,725	775,612	
1862	11,638	773,729	
1863	13,932	924,447	
1864	13,667	861,345	Production of Cornish mines and tin streams for ten years to end of 1871—
1865	13,867	767,680	
1866	13,601	658,686	
1867	10,988	545,238	
1868	11,530	638,052	Tons. 134,928 Value. £8,105,313
1869	13,756	879,997	
1870	15,190	998,963	
1871	16,759	1,057,176	
1872	12,156	1,053,001	
1873	14,660	1,034,693	
1874	14,686	746,328	
1875	13,800	690,592	Ten years to end of 1881—
1876	13,523	570,996	
1877	14,395	557,295	Tons. 138,521 Value. £7,098,129
1878	14,992	519,581	
1879	14,168	559,242	
1880	13,353	673,380	
1881	12,788	693,021	

[1] The ton of tin ore consists of 20 cwts. each of 115 lbs.

The largest production of tin ore in Cornwall was in the year 1871, but since 1873 the amount annually produced has not very materially fluctuated.

Copper mines do not appear to have been worked in this county until about the year 1700, although small quantities of copper ore were previously obtained from mines worked more expressly for tin. In 1838 the production of the copper mines of Cornwall amounted to 145,688 tons, each of 21 cwts., representing a money value of £857,779.[1]

On referring to the following table it will be seen that the annual production of the county has gradually decreased since 1855.

WEIGHT AND VALUE OF COPPER ORE OBTAINED FROM CORNISH MINES FROM 1855 TO 1881.

Year.	Tons.[1]	Value.	Remarks.
		£	
1855	161,576	1,064,474	
1856	163,958	1,019,176	Production for seven years
1857	152,729	979,565	to end of 1861—
1858	147,330	873,347	
1859	146,093	905,897	Tons. Value.
1860	145,359	873,471	1,060,164 £6,532,512
1861	143,119	816,582	
1862	141,810	728,299	
1863	129,221	642,944	
1864	127,033	659,918	Production for ten years to
1865	121,353	572,619	end of 1871—
1866	103,670	431,083	
1867	88,603	413,533	Tons. Value.
1868	86,722	373,005	973,494 £4,585,017
1869	71,790	316,364	
1870	56,526	242,227	
1871	46,766	205,025	
1872	41,756	226,654	
1873	40,285	188,236	
1874	40,455	201,367	
1875	39,393	204,228	Production for ten years to
1876	43,016	202,203	end of 1881—
1877	39,225	169,549	
1878	36,871	146,413	Tons. Value.
1879	30,371	116,168	362,619 £1,670,614
1880	26,737	111,408	
1881	24,510	104,388	

It will be observed that the production of copper ore in 1881 represented only one-tenth of the value of that raised in 1855. The average produce in metal of the copper ores of Cornwall is at present about 6$\frac{5}{8}$, although in 1848 it was as high as 8$\frac{3}{8}$.

[1] Copper and lead ores are sold by the ton of 21 cwts.

The following table shows a great falling off since 1845 in the quantity and value of the argentiferous lead ores annually produced in the county of Cornwall.

WEIGHT OF LEAD ORES OBTAINED FROM CORNISH MINES FROM 1845 TO 1881, WITH THE AMOUNTS OF LEAD AND SILVER RESPECTIVELY CONTAINED IN THEM, &c.

Year.	Lead Ore.	Lead.	Silver.	Value of ore.
	Tons.	Tons.		
1845	10,100	6,063		
1846	11,574	7,304		
1847	8,228	4,933		
1848	10,494	6,614		
1849	10,325	6,773		
1850	10,386	6,782	oz.	
1851	9,515	6,709	255,640	
1852	8,998	6,220	250,008	
1853	6,680	4,690	165,670	Average per ton
1854	7,460	5,005	179,675	£ s. d.
1855	8,962	5,882	211,348	14 4 6
1856	9,973	6,597	248,436	14 8 0
1857	9,559	6,036	224,277	14 15 0
1858	9,710	5,436	223,189	14 6 0
1859	7,842	4,985	215,964	13 16 0
1860	6,410	4,242	180,757	13 17 8
1861	6,690	4,228	173,344	12 10 7
1862	6,030	4,119	205,662	12 10 0
1863	6,259	4,270	206,312	13 1 6
1864	5,301	3,538	192,232	14 5 10
1865	6,546	4,296	214,659	12 14 7
1866	6,736	4,350	195,218	12 15 1
1867	8,645	6,480	314,326	12 17 6
1868	8,415	6,310	303,033	12 1 8
1869	9,023	6,775	315,714	12 5 6
1870	8,481	6,360	292,045	12 4 6
1871	7,564	5,073	267,324	12 6 0
1872	5,463	4,098	207,710	13 13 0
1873	3,909	2,923	129,509	15 8 0
1874	3,119	2,337	85,304	14 13 6
1875	2,566	1,932	25,681	15 9 3
1876	2,727	2,070	37,650	15 8 0
1877	2,166	1,674	23,035	13 19 0
1878	1,349	1,022	16,456	10 11 8
1879	725	545	9,435	10 6 0
1880	754	570	11,790	11 6 0
1881	765	409	14,396	10 3 0

		Tons
Total production of lead ore for ten years to end of	1861	82,284
,, ,, ,, ,,	1871	73,000
,, ,, ,, ,,	1881	23,543

DEVONSHIRE.—The mines of Devonshire are much less numerous and productive than those of Cornwall, which they, however, resemble in various other respects besides being for the most part situated in the approximate vicinity of the junction of clay slates and granite. The most important of the mining districts of this county is that of Tavistock, which includes the whole of the killas area extending from the river Tamar to Dartmoor, having a width from north to south of about ten miles. In this district are situated the celebrated copper mines of Devon Great Consols, formerly the most productive in Great Britain. This undertaking was started in the year 1844 with a capital of only £1,024, which was never increased by calls or otherwise; but in the course of the following twenty-one years a total profit of £1,000,000 was the result of the operations.

The mining field of Devon Great Consols comprehends several separate grants, all of which are connected by underground workings. The original sett was that of Huel Maria, the others having been subsequently added as extensions became desirable. There are six different lodes at the Devon Great Consols, namely, two to the north of the main lode, the main lode itself, and three others to the south of it; these, including the principal vein, have a direction varying from 12° to 20° S. of E. and N. of W. Their underlie is towards the S., and is on an average about two feet in a fathom.

The country rock is a kind of mottled killas, the spots in which are apparently caused by minute and imperfect crystals of andalusite. At one point the workings extend westward to the Gunnis-Lake mass of granite, but there are no elvans in the immediate neighbourhood of the mines. In the greater portion of the workings the walls of the lodes are well defined, this being more especially the case where they are most productive. The width of the main lode, which has yielded the principal portion of the copper obtained from the mines, is sometimes as much as thirty feet; while the others are considerably narrower and of less importance. There are ten known cross-courses at Devon Consols; one at Huel Maria has heaved the lode eighty fathoms to the right, but the other lodes have not been opened sufficiently near this cross-course to ascertain its influence upon them. What is known as the "Great Cross-course" is chiefly composed of flucan, with occasionally a little gossan near the surface. Spots of lead ore have also occasionally been found in the flucan. The lodes are, for the most part, composed of quartz associated with iron pyrites, arsenical pyrites, and copper pyrites, with sometimes a little tin ore; while carbonate of iron is usually present, not unfrequently forming the material cementing together the brecciated portions of the veins. One of the lodes in these mines sometimes assumes the appearance of having been filled with fragments of crushed killas, united by crystalline iron pyrites. When a lode of this description has been opened upon by levels or otherwise, the pyrites becomes rapidly oxidized, the veinstone is quickly disintegrated, and very heavy timbering is required to keep the ground open.

The ores raised at Devon Great Consols are usually of a low produce for copper, but they contain in addition a considerable amount of arsenic. A large proportion is consequently roasted previous to being sold as copper ore; this operation, in addition to yielding a valuable product in the form of white arsenic, materially increasing the percentage of copper in the residues. About six-sevenths of all the ores now sold are calcined for arsenic previous to being sent to market.

The principal workings of the mines do not extend to a depth much exceeding 220 fathoms below the adit, which is sixty fathoms from the surface; one shaft has, however, been sunk to a depth of 300 fathoms below the adit level, chiefly in the hope, which has hitherto been disappointed, of finding tin ore.

The workings comprise twenty-seven and a half miles of levels, six and a half miles of winzes and rises, and two and a half miles of vertical shafts. The largest return made in any one year was in 1857, when 28,836 tons of copper ore, of the value of £159,432, were raised and sent to market. The production of Devon Great Consols for 1881 was 10,922 tons of copper ore, of $4\frac{1}{16}$ produce, and of the value of £20,113. As before stated, the ores of these mines are usually arsenical, and during the year 1881 2,851 tons of white arsenic, of the value of £23,324, were prepared by calcination. Up to March 1882 Devon Great Consols has afforded 660,184 tons, each of 21 cwts., of copper ore, of the value of £3,344,446.

Bedford United Mines, lying about a mile south of Devon Great Consols, have for many years been a fairly productive undertaking. During thirty years ending December 31, 1881, these mines yielded 47,544 tons of copper ore, of the aggregate value of £113,298. The production of the year 1881 was 656 tons of copper ore, of $5\frac{3}{4}$ produce, representing a value of £1,997.

Huel Friendship, near Mary Tavy, which returned 110 tons of ore in 1811, was for many years a productive copper mine, but the yield of ore having become gradually reduced, the workings were ultimately suspended in 1857. The total yield of this mine during twenty-six years amounted to 32,250 tons of copper ore, of the value of £250,410.

Numerous lodes have at various times been opened in the neighbourhood of Bridestow and Okehampton, to the north of the

Tavistock district skirting the southern flank of Dartmoor, but in no instance does a profitable mine appear to have been discovered. In the Ashburton district, which includes all the area of clay slates skirting the eastern side of Dartmoor, and extending some miles north and south of Ashburton, are numerous lodes, some of which have yielded ores of copper and tin; they have, however, seldom yielded these ores in remunerative quantities.

Lead mining in Devonshire is of great antiquity, dating back to the time of the Roman occupation of the country. Some of the mines of this county were worked on account of the crown for the silver contained in the lead ore as early as the reign of Edward I., when they are recorded to have been profitable. The lead-mining districts of Devonshire are chiefly around Beer-Alston and Combe Martin. The mines of the latter district were re-opened in the reign of Elizabeth, and have been worked at various times since that period. Their working was strongly recommended to the Long Parliament in 1659, but they do not appear to have been again opened until the end of that century, and then without success. In 1813 they were re-opened and worked for four years, during which period they produced only 208 tons of lead ore. They were subsequently closed, and again worked in 1837. Of late years the most productive lead mines have been those in the neighbourhood of the Tamar, and the Exmouth and Frank Mills Mines on the banks of the river Teign, within ten miles of Exeter. One of the most productive of the Tamar mines was, some years since, flooded by the waters of that river breaking into the workings. A considerable amount of lead ore has also been raised at Christow.

The production of the lead mines of Devonshire has for many years been gradually declining, the total amount of lead ore produced in the county in 1881 being only ten tons. From 1851 to the end of 1863, a period of twelve years, the Tamar Silver Lead Mine yielded 7,910 tons of lead ore, containing 332,204 oz. of silver. The Frank Mills Mine from 1857 to the end of 1880, when the last sale of ore was made, a period of twenty-three years, produced 14,511 tons of lead ore, containing 247,151 oz. of silver.

Statistics relating to the production of Tin, Copper, and Lead Ores in Devonshire.—For many years past nearly the whole of the tin produced in the United Kingdom has been obtained from the mines of Cornwall, and during 1881 only 15 tons 8 cwts. 1 qr. 24 lbs. of black tin were raised from those of Devonshire. If, however, we make due allowance for tin ore obtained from streams, rivers, and foreshores, and add this to the above amount, the total yield of Devon can scarcely have reached, for that year, 75 tons, while during the same period the production of Cornwall may be taken at 12,788 tons.

Devonshire is said to have formerly produced a larger amount of tin ore than Cornwall; but if, from the production of the two counties together as given in the following table, we deduct each year the production of the latter county alone, as given in the table, page 146, we find that, for a period of nearly thirty years, the yield of black tin in Devonshire has been comparatively insignificant.

TIN ORE AND TIN PRODUCED IN CORNWALL AND DEVON FROM 1848 TO 1881.

Year.	Tin ore.	Metallic tin.	Value of tin ore per ton.			Value of metallic tin per ton.		
	Tons.	Tons.	£	s.	d.	£	s.	d.
1848	10,176	6,613		—		79	10	0
1849	10,719	6,952		—		78	15	0
1850	10,383	6,729		—		81	0	0
1851	9,455	6,140		—		86	15	0
1852	9,674	6,287		—		92	2	6
1853	8,866	5,763	68	0	0	120	0	0
1854	8,747	5,947	64	0	0	120	0	0
1855	8,947	6,000	68	0	0	120	0	0
1856	9,350	6,177	83	0	0	134	0	0
1857	9,783	6,582	76	0	0	130	0	0
1858	9,960	6,491	76	0	0	136	0	0
1859	10,180	6,497	74	15	0	132	10	0
1860	10,400	6,656	71	11	6	134	0	0
1861	10,963	7,016	62	6	8	136	0	0
1862	11,841	7,578	59	14	0	116	0	0
1863	14,224	9,104	63	12	0	117	0	0
1864	13,984	9,295	60	17	6	107	1	0
1865	14,122	9,038	55	6	0	96	15	0
1866	13,785	8,822	48	10	9	88	12	6
1867	11,066	7,296	50	18	0	91	17	3
1868	11,584	7,703	55	4	0	98	0	0
1869	13,883	9,356	69	16	0	123	2	0
1870	15,234	10,200	75	3	0	127	8	6
1871	16,898	11,320	78	12	6	137	10	0
1872	12,299	8,241	87	7	0	152	15	0
1873	14,837	10,006	78	1	0	133	7	0
1874	14,715	9,724	56	3	3	108	8	0
1875	14,004	9,614	52	11	6	90	2	0
1876	13,649	7,859	43	18	0	79	10	0
1877	14,091	9,423	40	10	0	73	3	6
1878	15,124	10,158	35	5	6	65	12	3
1879	14,280	9,282	40	0	0	72	6	0
1880	13,376	8,684	49	0	0	91	5	0
1881	12,898	8,615	54	0	0	97	9	3

The year of greatest production—1871.
The year of greatest value of tin ore and metal—1872.
The year of lowest value of tin ore and metal—1878.

WEIGHT AND VALUE OF COPPER ORE OBTAINED FROM MINES IN DEVONSHIRE FROM 1856 TO 1881.

Year.	Ore.	Value.	Remarks.
	Tons.	£	
1856	42,024	215,644	
1857	37,800	222,416	
1858	36,332	194,133	
1859	36,415	188,737	
1860	35,283	186,081	
1861	35,796	187,188	
1862	40,095	196,012	Production of copper ore for ten years to end of 1871— Tons. 335,072 Value. £1,437,881
1863	40,742	189,208	
1864	37,978	194,197	
1865	38,156	184,776	
1866	34,471	151,481	
1867	31,163	143,898	
1868	30,640	128,748	
1869	32,723	86,056	
1870	24,752	84,096	
1871	24,352	79,409	
1872	23,630	88,668	Production of copper ore for ten years to end of 1881— Tons. 156,211 Value. £523,975
1873	14,810	48,200	
1874	12,826	52,746	
1875	14,097	86,398	
1876	16,276	58,240	
1877	16,980	50,484	
1878	12,648	26,575	
1879	12,736	30,616	
1880	15,076	42,539	
1881	17,132	39,509	

According to statistics prepared by Her Majesty's Inspectors of Mines, and published since the foregoing tables have been in type, the production of tin and copper ores from the mines of Cornwall and Devonshire during the year 1882 was as follows:—[1]

Description of Ore.	Cornwall.			Devonshire.		
	Weight.		Value.	Weight.		Value.
	Tons.	Cwts.	£	Tons.	Cwts.	£
Black tin	12,189	5	723,774	50	8	2,652
Copper ore	25,641	1	114,688	19,201	0	66,133

The table on the following page gives the production of lead ore in Devonshire for thirty years, and shows the gradual falling off which has taken place in the yield of the lead mines of this county.

[1] *Mineral statistics of the United Kingdom of Great Britain and Ireland for the year* 1882.

WEIGHT OF LEAD ORES OBTAINED FROM THE MINES OF DEVONSHIRE FROM 1852 TO 1881, WITH THE AMOUNTS OF LEAD AND SILVER RESPECTIVELY CONTAINED IN THEM.

Year.	Lead ore.	Lead.	Silver.	
	Tons.	Tons.	Oz.	
1852	2,977	1,917	91,340	
1853	3,014	1,798	106,236	
1854	4,139	2,612	119,288	Production for ten years to end of 1861—
1855	4,035	2,292	89,908	
1856	3,138	2,000	77,456	
1857	2,590	1,535	50,262	Lead ore. Tons. 31,624 — Lead. Tons. 19,760 — Silver. Oz. 752,977
1858	2,779	1,695	53,366	
1859	3,172	2,090	66,875	
1860	3,018	2,030	53,059	
1861	2,762	1,791	45,187	
1862	2,079	1,376	39,265	
1863	1,578	1,080	20,357	
1864	1,656	1,093	21,480	Production for ten years to end of 1871—
1865	1,847	1,147	33,865	
1866	723	471	13,017	
1867	803	526	13,719	Lead ore. Tons. 13,463 — Lead. Tons. 8,997 — Silver. Oz. 247,530
1868	1,522	1,141	39,865	
1869	1,080	677	27,451	
1870	1,235	829	24,706	
1871	940	657	13,805	
1872	746	522	10,392	
1873	676	472	6,510	
1874	451	311	7,809	
1875	335	242	4,542	Production for ten years to end of 1881—
1876	437	327	5,890	
1877	337	252	4,948	Lead ore. Tons. 3,386 — Lead. Tons. 2,423 — Silver. Oz. 45,578
1878	234	169	3,286	
1879	129	97	1,915	
1880	31	23	226	
1881	10	8	60	

SOMERSETSHIRE.—Lead and zinc ores were formerly obtained from the Carboniferous Limestones of Somersetshire, but at the present time no mines for these metals are being worked in that county. A small quantity of lead is, however, still annually obtained in the Mendip Hills from the treatment of ancient slags and slimes, some of which are believed to be residues resulting from Roman workings.

Many important mines of spathose iron ore occur in the Brendon Hills in this county, and have for many years been worked by the Ebbw Vale Iron Company, who employ the ores obtained from them for the manufacture of spiegeleisen. Although this ore is of common occurrence in many parts of the Continent, it is in this country only found in considerable quantities in the following localities, namely, in Weardale in Durham, where, associated with lead and zinc ores, it forms veins in the Carboniferous Limestone, at Perran in Cornwall, at Exmoor in Devon, and in the Brendon Hills in Somersetshire, where it forms a chain of irregular lodes in slaty rocks of Middle Devonian age. The system of veins extends over a distance somewhat exceeding five miles, and their maximum aggregate thickness is about twenty-seven feet. The ore usually contains from 13 to 14 per cent. of protoxide of manganese, and yields spiegeleisen of good quality, containing about 20 per cent. of manganese.

The range known as the Brendon Hills runs nearly E. and W., and is about six miles south of that portion of the Bristol Channel lying between Watchet and Minehead. On their northern side they rise somewhat abruptly, but in the opposite direction their slope is much more gradual. At their highest point they reach an elevation of 1,350 feet above the sea-level, and the slates, which near the surface are grey in colour, acquire a bluish-green tint in depth, and usually dip towards the south-east. At Treborough, two miles north of the highest point of the range, these slates have been extensively quarried for roofing purposes. Attention was, in modern times, first directed to this locality by evidences of extensive ancient workings, with regard to the age of some of which there is no conclusive evidence; a coin of Domitian was, however, found in one of the old workings at Kennesome Hill, and Roman coins have been found in the vicinity of the old workings in the Brendon range. A wooden shovel and a turf dam were also found, in 1865, at the bottom of one of the ancient workings at a depth of 100 feet below the surface; this dam was apparently the last of a series extending from the top to the bottom, and by means of which the water was removed by dipping from one to another.[1]

The direction of the veins is usually N. of E., but their dip is variable. In addition to iron ores the lodes contain quartz, and occasionally fragments of the country rock. The quartz, which most frequently occupies the north side of the lodes, is not much intermixed with the ores, but more frequently assumes the form of distinct lenticular masses. Near the surface the carbonate of iron has everywhere been converted into brown hæmatite by the action of water and atmospheric air. The annual production of these mines amounts to about 27,500 tons.

THE FOREST OF DEAN.—The district known as the "Forest of

[1] Morgan Morgans, "The Brendon Hills Spathose Iron Ores and Mines," *Proceedings of South Wales Institute of Engineers*, vol. vi. p. 78.

Dean" is situated within that part of Gloucestershire which is bounded by the rivers Severn and Wye. This was probably one of the first seats of the iron trade in Great Britain, and its history is consequently of exceptional interest. In the reign of Henry the Second the Forest comprised the whole of the land lying within the above boundaries, but by successive reductions it has now become curtailed to the central district, occupying the area lying between Little Dean and Christ Church on the east and west, and Eccleswall and Bream on the north and south.

The strata of this district assume the form of a basin of which the greatest depression is near the centre; its longer axis extends for about eleven miles from N. to S., while the transverse axis in its widest part ranges about seven miles from E. to W. The central portion of this area consists of Coal-measures, which are surrounded by a belt of Carboniferous Limestone, which is itself bordered by Old Red Sandstone.

That the Romans carried on the manufacture of iron on a large scale, and for a lengthened period, in the Forest of Dean is sufficiently proved by coins and other relics of that people, which have been found under heaps of slags, which were once so abundant as to form an important proportion of the material supplied to the local iron furnaces. The earliest historical records respecting this district are clearly identified with its iron trade; for although the pages of the Domesday Book supply no definite information relative to this industry, they nevertheless distinctly allude to the production of iron in the immediate neighbourhood. It is there stated, however, that the bolts and bars required by the ship-builders of the Royal Navy were obtained from the city of Gloucester, and there can be little doubt that the iron was produced in the Forest of Dean. In the year 1140 the Abbey of Flaxley was founded by Roger, eldest son of the Earl of Hereford, by whom it was partially endowed, and by whom it was named the "Abbey of St. Mary de Dene," its site being at that time included within the precincts of the Forest. The institution of the abbey was confirmed by Henry II., who further enriched it by granting to the monks permission to feed their cattle and hogs in the Forest, to repair their buildings with its timber, and to establish iron forges within its boundaries. For a period of more than five centuries the iron trade established by the monks of Flaxley appears to have been carried on in almost any part of the Forest capable of furnishing the requisite ore and charcoal, and where a running stream supplied the power necessary for a blast.

The mineral district of the Forest of Dean is remarkable for the regularity of its strata, since each bed exhibits a continuous line of outcrop around the whole edge of the basin, with a uniformity without example in any other locality in this country. The Coal-measures are naturally divided into three series, of which the middle affords the greater portion of the large supply of coal now furnished by the district. The strata between the upper and middle series consist almost exclusively of argillaceous shales, with, here and there, thin beds of sandstone. Below the middle coal-seams the measures undergo a decided change, and instead of the shales before referred to, a hard sandstone prevails, and continues, with but little variation, down to the Coleford High Delf seam, which is one of the lowest belonging to the lower coal series.

The Farewell Rock or Millstone Grit, which underlies the Coal-measures throughout the Forest of Dean, contains, in its lowest bed, a deposit of iron ore which, to a small extent, is worked on its eastern outcrop; but the extensive deposits of ore, which from the earliest times have supplied the iron of Dean Forest, occur in large pockets or *churns* in the upper beds of the Carboniferous Limestone. Such churns often contain several thousand tons of brown hæmatite, which is for the most part soft and easily worked, but which, nevertheless, varies considerably in quality.

The Black Brush ore sometimes contains as much as 90 per cent. of peroxide of iron, but the poorer varieties, being contaminated by an admixture of clay and carbonate of lime, are proportionately less rich in iron. The most important workings in the limestone of this district are those situated on its eastern outcrop, where cavities in the almost perpendicular beds are filled with deposits of rich ores in enormous quantities. On the western side of the field, where the strata are less inclined than those on the other side, iron mining has long been extensively carried on. All the most successful mines, however, are found to lie to the dip of the excavations made by the ancient miners, who had frequently penetrated to greater depths than could have been expected when we consider the means at their disposal.

In accordance with the general practice among ancient craftsmen, the miners of Dean Forest were associated in a guild or trade corporation, and their prescriptive rights and privileges were guarded with extreme jealousy and care. For admission into this guild it was necessary that a man should have been born in the hundred of St. Briavels, and should have worked for a year and a day in either a coal or iron mine; he was then entitled to be admitted a Free Miner of the Forest of Dean.

The original laws of the Order of Free Miners as to modes of working and the extent of area allowed to each workman, were only applicable to very shallow workings. Consequently, in proportion as the demand for ore and coal increased and more expensive appliances for obtaining them from greater depths became necessary, the rules of the ancient code had, from time to time, to be relaxed in such a way as to afford opportunities for more extensive workings and the employment of larger capitals. This, however, resulted in endless disputes, until, under the Dean Forest Mining Act, commissioners were appointed to assign boundaries to the various mineral tracts, and to arrange the difficulties which the old Forest laws had been found inadequate to meet. The various collieries and iron mines of this district are now held under awards of these commissioners made in the year 1841. The present annual production of iron ore in the Forest of Dean is approximately 79,000 tons.[1]

IRON ORES OF THE CARBONIFEROUS LIMESTONE—NORTHERN COUNTIES.—The principal mass of the iron-producing Carboniferous Limestone of the northern and north midland counties of England emerges from beneath the Coal-measures of the counties of Durham and Northumberland in the east, and is bounded by a steep ridge overlooking the Vale of Eden on the west. It reaches its highest point in the mountainous range of Cross Fell, and forms a tract of moorland country which, in the neighbourhood of Alston, extends for a width of twenty-five miles, while in the elevated region adjoining the Scottish border it stretches almost completely across the island.[2] After an interval of a few miles the same formation again rises towards the west, from beneath the New Red Sandstone of Penrith, and the Coal-measures of Workington and Whitehaven, and forms a comparatively narrow belt around the older slaty rocks of the lake district. The structure of the high land, on which are situated the towns of Alston, Hexham, and Haltwhistle, differs materially from that of the contemporaneous formations occurring, both in England and Wales, further south, which, for a great thickness, consist principally of almost uninterrupted beds of limestone. In the north, on the contrary, the actual limestone plays a com-

[1] For information relative to this district consult "The Forest of Dean," by Rev. G. H. Nicholls, 1858; also Arnold Thomas, "The Forest of Dean," *Proceedings S. Wales Inst. of Engineers*, vol. vi. 1870, p. 200.

[2] W. W. Smyth, "The Iron Ores of Great Britain," *Memoirs of the Geological Survey*, 1856, part i. p. 15.

paratively subordinate part, and alternates with strata of sandstone and shale, locally known as *hazle* and *plate*. In some of these bands of shale are found nodules of clay ironstone, of which the aggregation and mode of occurrence exactly resemble those of similar ores in the Coal-measures.

The majority of the mineral veins of the vicinity of Alston, which produce the lead ore for which that district is celebrated, range nearly east and west, and intersect the whole of the strata belonging to the Carboniferous Limestone; they are, however, much more productive in certain of the beds than in others. Some of these lead veins in portions of their course, instead of being composed of the usual veinstones accompanying lead ore, such as calcite, fluor spar, &c., are filled with brown iron ore. The rich lode of Rodderup Fell, known as the Craig Green or Bracken Syke Vein, in the "Scar Limestone," belongs to this class, and varies from sixteen to twenty feet in width. Certain of the lodes in the

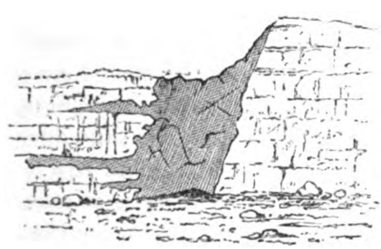

FIG. 47.—Section of Manor House Lode.

vicinity of Alston, producing ore of this kind, have been extensively wrought. Among others the Manor House Vein, near the railway station, has yielded large quantities of brown iron ore of good quality. This vein is about twelve feet in width, and its productiveness is increased by the occurrence of flats, which, at distances of a few feet apart, penetrate between the bedding of the limestone which constitutes the country rock. Fig. 47 is a diagrammatic sketch, given by Smyth, representing a section of this lode. On the northern shoulder of Cross Fell, and in Weardale, outcrops of similar iron veins occasionally present themselves.

In the eastern part of this region spathose iron ores make their appearance abundantly in the lead veins, and form the veinstone accompanying galena, for which the mines are principally wrought. At the mines of Allenheads spathose ore occurs both in regular veins and in flats, while at Stanhope Burn the veins are so charged with this mineral that at a spot where several of them occur in close proximity to one another, and which is further enriched by the interlacing of numerous strings, the whole surface has been removed by the Weardale Iron Company, and the rock taken away by quarrying, a considerable amount of lead ore being separated during the operation. In many places in this district brown peroxide of iron is frequently mingled, especially near the surface, with spathose ore, from which it has doubtless been derived.

The red hæmatite from the vicinity of Whitehaven in Cumberland, and of Furness in Lancashire, is obtained either from Carboniferous rocks or from those of Silurian age. Practically, however, it is almost entirely derived from the former, since the deposits in the Silurian rocks are of extremely limited extent. The Carboniferous Limestone series, in which the principal deposits occur in both districts, consists mainly, as before stated, of alternations of limestones with shales and sandstones.

The sandstones and shales are generally very thin, often not more than two or three feet, and seldom exceeding twelve feet, in thickness. On the other hand, the limestone occurs in enormous beds, sometimes exceeding 300 feet in thickness, and it is in these thick masses of Mountain Limestone that the hæmatite is principally found. The ore fills fissures and lake-like basins in this rock sometimes immediately below the drift, while at others it presents itself in an irregular form deep down in the Carboniferous Limestone. It is found in almost every bed, from the lowest, resting on the Silurian, to the highest, forming the base of the Grits and Yoredale rocks, at Whitehaven and Furness respectively. It is evident, therefore, that there is a wide difference in the geological horizon of the various deposits. In consequence, however, of the inclination of the limestone and the extent to which it has been denuded, this difference of geological horizon does not always affect the actual level of the deposits, and many of them occurring in the lower beds are found much nearer the surface than those in the higher ones.

At Whitehaven, some of the finest deposits of iron ore occur in the upper beds of limestone, that is, in those lying immediately below the Grits. At Bigrigg, Crowgarth, and Parkside, the ore is found in large, irregular masses in the limestone immediately under the Millstone Grit, one of the beds of which forms in each case the roof of the deposit. In section these deposits present in many respects the appearance of a bed, since they follow the dip of the rocks in which they lie, and usually preserve a tolerably uniform thickness, which in different deposits varies from four to above forty feet. The roof of sandstone, and the floor of limestone are, in some cases, parallel for very considerable distances; at Parkside, for instance, the roof and floor remain parallel for a distance of nearly 200 yards. Fig. 48, from a sketch by Mr. J. D. Kendall, represents a vertical section of that deposit taken along its line of dip.[1]

This affords a striking example of the way in which such deposits sometimes vary in thickness. To the left of *a* the depth of the ore is not less than sixty-five feet, while at *b*, only a short distance from it, it does not exceed four feet. These variations in thickness are always due to irregularities in the limestone floor, as the roof invariably forms a regular even plane having the same general dip as the strata surrounding the ore. These variations in thickness usually take place in the direction of the

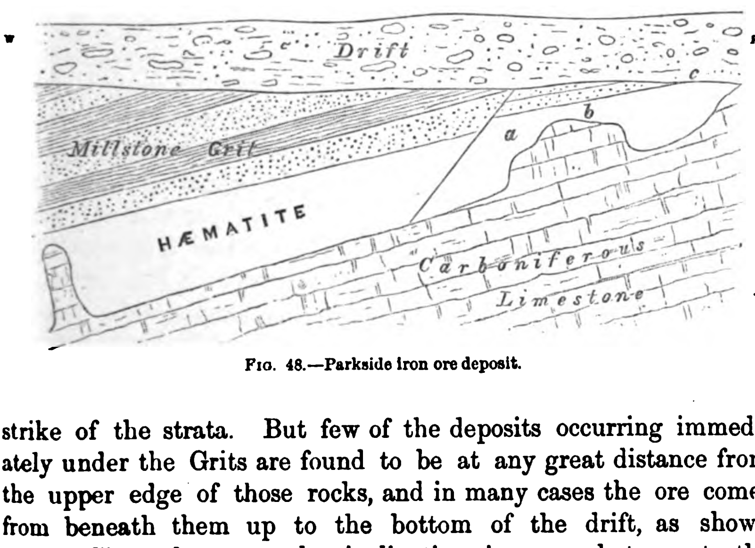

FIG. 48.—Parkside iron ore deposit.

strike of the strata. But few of the deposits occurring immediately under the Grits are found to be at any great distance from the upper edge of those rocks, and in many cases the ore comes from beneath them up to the bottom of the drift, as shown at *c*. Since, however, the inclination is somewhat great, the deposit, as it extends towards the dip, rapidly becomes covered by a considerable thickness of rock. The superficial extent of these deposits is sometimes very large, that at Parkside having an area of eighteen acres, while numerous others vary in size from two to ten acres.

In Furness one deposit only has, as yet, been discovered in the highest bed of limestone lying immediately beneath the Yoredale

[1] "The Hæmatite Deposits of Whitehaven and Furness," *Trans. Manchester Geol. Soc.*, vol. xiii. 1876, p. 231.

rocks. This deposit is at Stank, and was discovered in searching for coal.

The deposits in the intermediate beds are many and various. Some of them, and especially those in Furness, lie immediately below the drift in basins hollowed in the limestone similar to those which occur in the lower beds. Others, and particularly at Whitehaven, are at considerable depths in the limestone enclosed in irregular caverns, which are sometimes at a depth of 35 fathoms from the surface, and are surrounded by limestone on all sides. A good example of a lake-like deposit is seen, Fig. 49, at the open cutting of the Crossfield Iron Company. In Furness there are a great number of shallow basin-like deposits, all those in that district, with but few exceptions, belonging to this class.

The deposits in the lower beds of limestone resting upon the Silurian rocks are among the finest which have been found in the Furness district. Amongst these may be mentioned those of Park

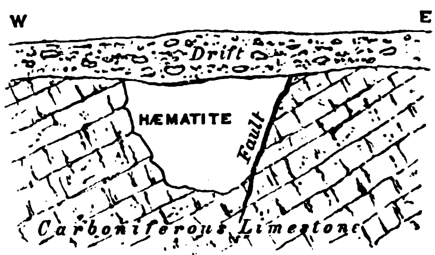

FIG. 49.—Open works; Crossfield Iron Company.

and Lindal Moor, the first of which extends over an area of fifteen acres, and at one point has been proved to a depth exceeding 300 feet. The deposit at Lindal Moor is 900 yards in length and about twenty-three yards wide. One or two very fine deposits of hæmatite occur in the lower limestone beds at Whitehaven, such as those at Todholes and Woodend. The lower deposits usually occur in dishes or hollows in the limestone immediately below the drift, and in close promixity to rocks of Silurian age. Sometimes they even rest upon Carboniferous Limestone on one side and upon Silurian rocks on the other, as shown in Fig. 50. Both the Park and Lindal Moor deposits rest partly on Silurian rocks, as do also those of Todholes and Woodend. At Martin, in Furness, there is a deposit of this class which, on account of the peculiar circumstances under which it occurs, is worked like an open quarry. When first discovered the ore was covered by about thirty feet of drift, which has since been removed, thus affording an opportunity of thoroughly examining its form and character. It lies on the limestone, by which on all sides, except one, it is surrounded. Where the limestone is absent the ore rests upon the underlying slate, which rises at a high angle from below that rock. The length of this deposit is about 260 feet, and its width 200 feet, while the greatest depth to which it has yet been proved is somewhat over fifty feet.

Wherever these deposits occur, whether just below the Grit, in the middle of the series, or down upon the Silurian slates, their longer axis almost invariably coincides with the direction of the principal joints of the limestone rock.

At Whitehaven the hæmatite is usually of a dull red colour, and occurs in hard compact masses containing numerous irregular cavities, which are frequently lined with a botryoidal concretion

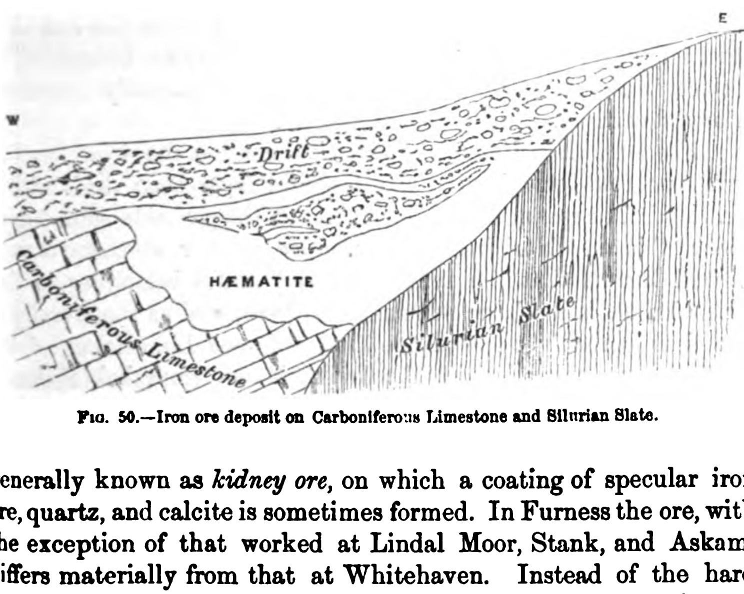

FIG. 50.—Iron ore deposit on Carboniferous Limestone and Silurian Slate.

generally known as *kidney ore,* on which a coating of specular iron ore, quartz, and calcite is sometimes formed. In Furness the ore, with the exception of that worked at Lindal Moor, Stank, and Askam, differs materially from that at Whitehaven. Instead of the hard solid masses met with in that district, the Furness ore consists, to a large extent, of a loose incoherent material composed of delicate filmy scales of micaceous iron, soiling the fingers when touched, and enclosing fragments of more compact ore, many of which have a concretionary structure. The harder hæmatite, locally known as *blast ore,* is entirely employed for smelting purposes, while the softer variety, sometimes known as *smitty ore,* is much used for the purpose of forming the bottoms of puddling furnaces. Some of the harder ores of the Furness district exhibit very distinct lamination, and concretionary nodules of hæmatite are met with which, on being broken, are found to contain a nucleus of limestone. No fossils have ever been found in the soft crystalline ore of Furness, but large numbers, all belonging to the Mountain Limestone series, occur in the more solid ores of Lindal Moor. It would appear probable that the hæmatite which now fills the basins and hollows of the Carboniferous Limestone, was originally deposited in the form of carbonate of iron. It will be easy to conceive that, on a solution of this substance in water containing carbonic acid coming in contact with limestone, the carbonate of iron would be deposited, and its place in the solution occupied by carbonate of lime. When the carbonate of iron had been thus formed, its change into hæmatite was probably effected by a process somewhat analogous to that by which siderite is so often seen to become converted into brown iron ore. That a portion at least of the hæmatite has replaced carbonate of lime becomes evident from the fact that numerous fossils of the Carboniferous Limestone have been found in the ore, and that some of them have only been partially converted into oxide of iron.

It is somewhat difficult to conceive whence the iron forming such numerous ferruginous deposits could have been derived, but Mr. Kendall suggests the Coal-measures as the probable source from which this metal originally came. He further remarks that it is well known that the sandstones and shales belonging to this formation contain a large percentage of iron; and as these rocks at one time probably overlaid the Carboniferous Limestones of the hæmatite-producing districts, he thinks it not improbable that a large proportion of the iron in the limestones may be the result of the percolation of waters, charged with carbonic acid gas, through superincumbent beds which have been since removed by denudation.

In 1881, the production of red hæmatite in Cumberland was 1,615,635 tons, while that of Lancashire amounted to 1,189,836 tons.

IRONSTONES OF THE COAL-MEASURES.—The clay ironstones of the Coal-measures, which have so largely contributed to the prosperity of the iron trade of this country, often form layers of more or less regular nodules enclosed in beds of shale and clay belonging to that formation. They occasionally coalesce into beds, which are seldom of any considerable extent or thickness. These nodules consist essentially of carbonate of iron, associated with varying proportions of the carbonates of lime and magnesia, together with a certain amount of argillaceous matter;

they also usually contain a little carbonate of manganese. Such nodules are often concretionary, and contain fresh-water shells, remains of fish, fragments of plants, and other fossils. The concretions are sometimes of such small size that they have received the name of *pins, pennystones*, and other similar appellations; occasionally they are large spheroidal masses exceeding a foot in diameter. The larger nodules are frequently divided by irregular cracks which are usually filled by such minerals as calcite, quartz, iron pyrites, chalcopyrite, blende, and galena. Millerite or sulphide of nickel and mineral tallow occur together in the nodules of clay ironstone of Glamorganshire. When recently broken, nodules of ironstone commonly exhibit a light grey or bluish tint, which on exposure to the atmosphere rapidly becomes brown through oxidation.

Ores of this character almost invariably contain phosphoric acid, of which the proportion occasionally exceeds one per cent. Clay ironstone sometimes exhibits the regular structure known as *cone in cone*, in which case the seam has a tendency to divide into cones, the bases of which are towards the top and bottom of the bed, while their apices are directed towards the centre. The English coal-fields most plentifully supplied with ores of this class are those of Staffordshire, Shropshire, Yorkshire, and Derbyshire; while but little is found either in Northumberland, Durham, or Lancashire. Clay ironstones are worked both in North and South Wales and in Scotland. They are sometimes brought to the surface through the pit employed for extracting the coal, but at others they are obtained by entirely independent workings. To give the names only of all the numerous localities which have in this country furnished clay ironstone from the Coal-measures, would occupy more space than can be devoted to the subject; but a brief notice of one or two of the more productive localities may, nevertheless, not be out of place.

In the northern district of Yorkshire, the lower series of the Coal-measures is developed to an extent not observable in the south by the occurrence of beds of coal and ironstone which have given rise to the establishments of Low Moor, Brierley, Bowling, &c., celebrated for the production of the best iron made anywhere in Great Britain. Coal-measure ironstones are alone employed in this district, and are principally derived from two groups of strata, known respectively as the White-Bed Mine and the Black-Bed Mine; a third, called the Brown Rake, was also formerly worked. The ores are not without phosphorus, and neither their abundance nor their by rootlets of stigmaria, which are sometimes filled with blende. The most remarkable of all the ironstones of the district is the Black Shale Rake, which is nowhere so well exposed as at Hady, near Chesterfield, where it has been long extensively worked for the use of the blast furnaces at Staveley. At this place it consists of two distinct bands of grey shale respectively 15 and 21 feet in thickness, loaded with numerous rows of ironstone nodules, and separated from one another by 12 feet of unproductive shale. Among the ironstones of this deposit the "cheeses" are remarkable for the symmetrical cracks caused by contraction; these are mostly filled with carbonate of lime, containing iron and magnesia, but open cavities lined with crystals of blende are of frequent occurrence. The "Old Man" and "Old Woman" are compact grey ironstones with a somewhat conchoidal fracture which exhibit numerous cracks, and these, in addition to impure carbonate of lime, contain well-defined crystals of blende and galena. Copper pyrites and iron pyrites sometimes occur in the same way, and not unfrequently occupy the hollows left around the casts of fossil shells. The upper measures of the Dale Moor Rake, the lowest known in the Derbyshire coal-field, yield an ironstone of a light drab colour, which is remarkable for the number of plant remains, particularly rootlets of stigmaria, which it encloses. The "Bottom Balls" are especially remarkable for containing a large number of entire fishes, usually from four to seven inches in length, belonging to the genera *Palæoniscus* and *Platysomus*. The large number of courses in these lower ironstone measures, together with the great thickness of the shales in which they occur, renders it necessary to work them by open cuttings on a very large scale.

The yield of ironstone per acre must necessarily depend on the thickness of the nodules in the measures and the closeness and regularity of their distribution. The Tankersley Mine, in Yorkshire, a bed of shale about six feet in thickness, contains from twelve to fifteen inches of ironstone, and yields, on an average, 2,000 tons per acre. At Parkgate the Old Black Mine, 11 inches thick, yields 1,500 tons per acre, while the Clay Wood Mine, only five and a half inches in thickness, produces from 1,500 to 1,600 tons per acre. In Derbyshire, at Butterley, the Brown Rake, consisting of three thin measures of ironstone in a band of shale, of the total thickness of four feet six inches, yields 2,500 tons per acre.

The Chesterfield Black Shale Rake, which is the most productive in the district, consists of twenty bands of ironstone nodules varying from half an inch to two and a half inches in thickness, aspect to the country. The pits and irregular openings thus extending over considerable areas, render them totally unfit for cultivation, and these old workings having been planted, the line of outcrop of the ironstone is often distinctly indicated by the belts of trees.

The more important of the ironstone beds worked in the West Riding are comprehended within a thickness of about 1,000 feet of measures extending between the Barnsley Thick Coal and the Silkstone; they are known as the Swallow Wood, Lidgate, Tankersley, Thorncliffe Black Mine,[1] Thorncliffe White Mine, and Clay Wood Mine.

The Derbyshire coal-field being the extension, southward, of that of Yorkshire, many of the same seams may be traced continuously over a large area. The ironstone beds, however, usually possess less persistency of character than the coal-seams, and comparatively few of them continue to be productive throughout the whole length of the county. On the contrary, many of the seams of nodular ironstone, locally called "rakes," which in certain districts are extensively worked, are found, within a comparatively short distance, either to thin out, or to so deteriorate in quality as to be unworkable.

The total thickness of the Derbyshire Coal-measures may be taken at about 2,000 feet, including the very productive seams of the Pender Park, Staveley, and the Cement Rake and Brown Rake of Alfreton and Butterley. The Dog-tooth Rake of Chesterfield, 24 feet in thickness, is one of the most important in this field, and is remarkable from the fact that one or more of its beds are almost entirely composed of fossilized shells of *Anthracosia*. This shell, probably of several species, is found in great abundance in all the upper beds of ironstone. In some of the lower measures, it is either less numerous or is altogether wanting; among the very lowest, however, it again appears.

With regard to the prolongation of these beds southward, much confusion has arisen from the same name having been given to distinctly different beds, yielding ores of a somewhat similar character. The Three-quarter Balls form a very productive seam below the Furnace Coal at Clay Cross. Many of the lower ironstones contain, in addition to bivalve shells, the remains of various coal plants, which frequently form the surface of a nodule, and have become completely converted into iron ore. The balls of ironstone in this neighbourhood are often pierced by small tubular hollows left

[1] In the iron districts the word *mine* is often used as synonymous with *ore*.

The inner portions of concretionary masses of this iron ore often consist, for the most part, of carbonate of iron, while the outside is entirely composed of brown hæmatite, the latter having evidently been derived from the former through the action of atmospheric influences. Analysis shows that the greyish mineral of the Northamptonshire ores contains from 60 to 80 per cent. of carbonate of iron, with from 10 to 25 per cent. of insoluble matter chiefly consisting of sand and siliceous oolitic concretions. Besides these, but existing in smaller proportions, are the carbonates of lime and magnesia, with carbonaceous matter, water, sulphur, and phosphorus. The last of these bodies is, unfortunately for the value of the ore, invariably present, and frequently in considerable quantity.

Mr. S. Sharp has noted the following divisions of the beds in the Northampton district [1]—

	Feet.
4.—White or grey sand and sandstone, sometimes quarried as building-stone, containing a plant-bed	12
3.—Thin ferruginous sandstone and shelly ferruginous beds, very variable, being sometimes entirely calcareous, at others consisting of white sand and sandstone	30
2.—Coarse oolitic limestone	4
1.—Ironstone beds containing *Rynchonella variabilis*, *R. cynocephala*, *Ammonites bifrons*, &c. .	35
Upper Lias Clay.	

At Banbury the beds are only twelve feet in thickness.

The Northamptonshire sands include the lower estuarine series of Professor Judd, which comprehends the brown and white sands with argillaceous beds and plant-remains occurring above the fossiliferous beds of ironstone. It would appear from the investigations of this geologist that, although in the southern part of Oxfordshire and in South Northamptonshire the Northampton sands are the equivalent of the lower zone of the Great Oolite and of part of the Inferior Oolite, in the northern part of Northamptonshire and in Lincolnshire they include the lower estuarine series, and occur beneath the Collyweston slates and Lincolnshire limestone of the Lower Oolite. In Wiltshire the same ore

[1] "The Oolites of Northamptonshire," *Quart. Jour. Geol. Soc.* vol. xxvi. 1870, p. 354.

occurs in the Coral Rag, and in Buckinghamshire in the Lower Greensand. In the latter locality the bed is not continuous, but nodular masses of limonite are scattered through a stratum of brown sand about fifty feet in thickness. The nodules of ironstone are frequently hollow and enclose loose white sand. After a careful study of the district, Professor Judd has arrived at the following conclusions relative to the origin of the sands and iron ores of Northamptonshire.[1]

"We find in what is now the midland district of England, and at a period separated by a long interval of time from that of the last deposit in the area, the Upper Lias Clay, that a number of considerable rivers, flowing through the Palæozoic district lying to the north-west, formed a great delta. Within the area of this delta the usual alternations of marine, brackish water, and terrestrial conditions occurred, and more or less irregular accumulations of sand or mud in strata of small horizontal extent, took place. Subsequently, and probably in consequence of the gradual depression of the area, the conditions were changed, and in an open sea of no great depth by the abundant growth of coral reefs and the accumulation of dead-shell banks, during enormous periods of time, the materials of the great deposits of the Lincolnshire Oolite limestone were formed. On a re-elevation of the area the former estuarine conditions were also re-produced, and similar deposits, but of an argillaceous rather than an arenaceous character, were formed. Confining our attention to the earlier of these two estuarine series, that of the Northampton sand, we must imagine the beds as being carried down to great depths in the earth by the deposition upon them of the superincumbent strata. But at the same time another most important cause has come into operation, namely, the passage through some portions of the rock of subterranean water containing carbonate of iron in solution. By this agent, carbonate of iron was deposited in the substance of the rock, while portions of the siliceous and other materials were dissolved; and these entering into new combinations, were in part re-deposited in the mass of the rock in the form of oolitic grains, and in part, probably, carried away in solution. During the existence of the beds under a great pressure of overlying rocks, they would likewise become consolidated and jointed. These metamorphic processes would probably take place with extreme slowness and may possibly be still going on, where the rock remains deep seated in the earth; by their means, portions, greater or less, of the sandy

[1] "Geology of Rutland," *Mem. Geol. Survey*, 1875, p. 136.

strata, but always those resting immediately on the impervious Upper Lias Clay, would be gradually converted into solid and jointed rock beds, composed principally of carbonate of iron. The next stage in the course of alteration in these rocks would commence when, by the action of denudation, portions of them were brought again near the surface so as to be traversed by the atmospheric waters entering them as rain, and passing away from them as springs. The action of this water is, as we have seen, to remove the carbonic acid and soluble salts, to change the protoxide of iron into hydrated peroxide and to re-distribute it in such a manner as to produce the remarkable cellular structure of the rock, and also the mamillated, botryoidal, and sculptured surfaces. Finally, by mechanical, as distinguished from chemical, sub-aerial denudation, the beds of Northamptonshire iron ore nearest the surface are disintegrated and broken up, and the softer and less ferruginous portions to some extent carried away in suspension, and thus deposits composed of the harder and denser materials formed, constituting the bed usually worked as an iron ore."

The history of the working of the ores from the Oolite of the Midland district is a somewhat remarkable one. There is evidence that as long ago as the Roman occupation of the country these beds of iron ore were extensively worked, since in a wood near Oundle, heaps of broken ore, piles of the same ore after calcination, and very large quantities of slag are found associated with Roman coins and pottery. It is further known, from existing documents, that during later times Rockingham Forest vied with the Weald of Kent and Sussex as an iron-producing district. In both these areas the presence of beds of iron ore in the close proximity of an almost unlimited supply of timber, had, at an early date, led to the erection of numerous forges of the kind then employed for the manufacture of iron. Throughout nearly the whole of the Northamptonshire district large accumulations of rich iron slags are still met with. They are dark in colour, very heavy and compact, and apparently contain a large proportion of the iron originally present in the ores treated.

The re-introduction of the Northamptonshire ore into the iron trade is of comparatively recent date, and is principally due to the exertions of Mr. S. H. Blackwell, of Dudley. In the year 1851, Dr. Percy directed the attention of this gentleman to a specimen of iron ore which he had received from the district in question. Mr. Blackwell thereupon inspected the locality, and his investigations resulted in the discovery of an extensive deposit of ore, the importance of which to the iron trade of the present day is very great.

In Lincolnshire, iron ore occurs in the Lower Lias limestones and shales characterised by a great abundance of *Gryphæa arcuata*. The ironstone bed, which is 27 feet in thickness, is worked at Scunthorpe and Froddingham in the northern part of the county. Two beds of ironstone, measuring respectively 4 and 8 feet in thickness, are met with in North Lincolnshire, and are probably the equivalent of some of the Cleveland ironstones. The Marlstone rock yields a good ironstone in some parts of South Lincolnshire, and evidence still exists of its having been formerly worked.

The Northampton-sand ores were in former times extensively dug in South Lincolnshire, but at the present time no workings in this formation are being anywhere carried on within the limits of the county.

The Ironstone Junction Bed at the base of the Upper Estuarine series, the equivalent of the Stonesfield Slate of the south of England, is a band of good ironstone about a foot in thickness, which has been worked at various times, although not recently. A few years since a considerable amount of ironstone in the form of balls was obtained from the Great Oolite Clay at Overton, near Peterborough, but the workings have been abandoned in consequence of the large amount of waste material it was found necessary to remove.

In the beds of the Tealby series, Middle Neocomian, is found a brown oolitic ironstone in a bed averaging nearly six and a half feet in thickness; this ore closely resembles that worked near Salzgitter in Hanover, and is of the same geological age. Fossils are extremely numerous in this deposit, and the ore, which is highly calcareous, contains from 28 to 33 per cent. of iron. It is much used for mixing with certain clay ironstones from Yorkshire.

The Upper Sandstone Shale and Coal of Professor John Phillips, probably of the age of the Great Oolite, contains, in Yorkshire, bands of ironstone in nodules, some of which have been formerly worked. The Lower Sandstone Shale and Coal of the same author, equivalent to the upper part of the Inferior Oolite, also contains similar nodules.

The celebrated ironstone of Cleveland occurs in the Middle Lias, and is divided by bands of shale and pyrites into several beds. Where best developed it has a total thickness of above twenty feet, the two principal beds being known respectively as the *Pecten* and *Avicula* seams, from the prevalence in them of fossil shells belonging to those genera.

The usual colour of the ore is a dull bluish-green, arising from the presence of silicate of iron; its structure is oolitic with numerous interspersed fossils. As raised from the mine these ores contain from 28 to 32 per cent. of iron, and the beds worked extend, inland, from Redcar to Eston near Middlesborough, on Tees. At Eston the main bed attains its greatest thickness, presenting in some places a section of nearly twenty feet of undivided ironstone. From Eston the bed gradually, but slowly, thins off towards the south-east, but in the opposite direction this takes place more rapidly. The whole of the workable Cleveland ironstone is in the highest part of the Middle Lias, the yield per acre varying from 20,000 to 50,000 tons.

The "Dogger" includes the lower part of the Inferior Oolite and the sands below it; and in some places, as at Rosedale, these form a rich iron ore. This ironstone, which is magnetic and polar, sometimes contains as much as 50 per cent. of iron, and has a greenish, blue, or black colour, with the imperfect oolitic structure observable in unweathered specimens of Northampton-sand ore.

The production of iron ore in the Cleveland district during the year 1881 amounted to 6,538,471 tons.

That of Northamptonshire was 1,270,544 tons; of Lincolnshire, 1,021,506 tons; of Wiltshire, 39,222 tons; and of Oxfordshire 8,614 tons.

SHROPSHIRE.—Shelve, a remote parish in the western part of Shropshire, is situated in the centre of a tract of country where Silurian strata of Llandeilo age are prominently developed. Although the stratified rocks in the district around Shelve principally belong to the Llandeilo formation, they are to some extent surrounded by a fringe of Upper Llandovery and Wenlock deposits, which repose unconformably upon them. On the east, the Llandeilo and the Lingula Flags rest on the Cambrian strata of the Longmynd range.[1]

The strata of the Lower Llandeilo series are of a very uniform character, consisting of fine-grained shales which vary considerably in hardness, but which never present any indication of slaty cleavage. When first brought to the surface out of the mines the fracture of this rock exhibits a massive slaty character, but

[1] G. H. Norton, "The Geology and Mineral Veins of the Country around Shelve, Shropshire," *Proc. Liverpool Geol. Soc.* September, 1869.

after being for some time exposed to the action of the atmosphere it splits along its planes of bedding, and assumes the appearance of a shale. At the surface is principally a soft, splintery shale, but in the vicinity of the numerous greenstone dykes it frequently becomes a hard ,slaty rock. Generally speaking, the strata are nearly black, although shales of a light shade occur with less frequency; while in certain localities thick flagstones are interstratified with the other rocks. The lead veins of the Shelve district have probably been worked, at various intervals, from a period shortly after the Roman occupation of Britain, as the discovery of pigs of lead bearing the inscription of IMP HADRIANI AUG. shows that, at the Roman Gravels Mine, ore was being raised and smelted early in the second century of the Christian era. The only extensive ancient excavations are those at the Roman Gravels Mine, which still continues to be the most productive in the district. These openings originally consisted of three cuttings following the course of the Sawpit, Roman, and Second North Veins, and extending in the form of furrows up the hill side and over its crest. Those on the outcrops of the two first named veins are still distinctly traceable, but that on the Roman Vein is by far the most important excavation. In its present condition, this presents the appearance of a deep trench extending up the side of the hill, continued over the top, and, finally, ending in a series of shaft-like openings, of which the mouths have generally fallen together. At the end of the main opening, which is about 100 fathoms in length, the lode has been followed underground, and its contents worked out. The width of the vein, where it is visible, is from 2 to 6 feet, and the open workings on the back vary from 25 to 50 feet in depth. Lower down in the mine the width of the lode varies from six inches to ten feet. Immediately beneath the point at which the ancient miners finally suspended their operations, a large mass of galena was found.

There are five different lodes at this mine, all of which are comprehended within a strip of ground not exceeding 370 yards in width; these are named, respectively, the Spring, Sawpit, Roman, First North, and Second North Veins. The Second North and Roman Veins run nearly parallel to one another; both having a direction N. of W. and S. of E., with a dip towards the N.E. The First North, the Sawpit, and the Spring Veins are also nearly parallel, but take a more westerly course. The First North Vein has a S.W. dip, while that of the other two is in a contrary direction. Both the Sawpit and Spring

Veins are intersected at a small angle by the Roman Vein. The lodes are to a large extent composed of calcite with a certain amount of quartz, and in addition to galena they contain blende and iron pyrites; but few druses are found in them, and well crystallized minerals are of rare occurrence. At the Oven Pipe Mine in this district the lode sometimes contains small cavities enclosing bitumen.

The Roman Vein is by far the most important, and, in modern times, has yielded fully seven-eighths of all the ore which has been raised from the mines. It is still producing a considerable quantity of lead at the depth of 100 fathoms below the surface. None of the veins have ever been worked more than a few fathoms beyond the road leading from Bishop's Castle to Minsterly, as the strata there change from a hard slaty rock into a soft shale, in which they die out. A dyke of eruptive rock traverses the Roman Vein and hardens the rock in its vicinity. This vein has been followed in a south-easterly direction, and was lost in soft shales as at the other extremity.

During the year 1881 the Roman Gravels Mine produced 2,921 tons of lead ore, of the value of £28,109.

Next after the Roman Gravels, the most important mine of the Shelve district is Snailbeach. This, which is a very old working, is situated to the north of the Gravels Mine, has been wrought for a long period, and, after having been with the Bog Mine, now abandoned, the richest in the neighbourhood, still yields a considerable annual return of lead.

The workings are exclusively confined to one large lode, although the existence of another to the south of it, and consequently called the "South Lode," has been satisfactorily established. The country rock is a hard, quartzose, slightly micaceous schist, of a greenish-grey colour, and of Llandeilo age, which dips W.N.W. at an angle of 60°, conformably with the Stiperstones; the strike of the bedding ranges N. of E. and S. of W., parallel with the Longmynd system. In the western part of the mine there are alternations of soft shale with the harder rocks.

The average bearing of the lode is nearly true E. and W., but for short distances it varies considerably from this course. It crops out in the side of a hill facing the north, under which it dips with a tolerably regular underlie of two feet in a fathom; its richest portions usually bearing nearly E. and W. The levels on the course of the lode are fifteen fathoms apart, and are connected with a shaft about 200 fathoms in depth, by cross-cuts. In length the workings have been extended 400 fathoms east and 200 fathoms west of the shaft.

The line of junction between the lode and the bedding of the strata dips west at an angle varying from 45° to 55° with the horizon; this is precisely the dip of the shoots of ore, which are remarkable for their regularity. A section showing the general arrangement of the shoots of ore in this lode is given in Fig. 32, page 50. Six principal shoots of ore have been discovered at Snailbeach, and at a point west of the shaft the ore was, in one level, as much as 75 fathoms in length; still further west, the alternations of soft shale with micaceous schist correspond with the complete impoverishment of the lode, which becomes of no value in these soft bands. In its richer portions its width sometimes reaches ten feet, but when passing through shale it is usually very small as well as unproductive.

The principal constituents filling the vein fissure are calcite, which is often well crystallized, and forms a large portion of the veinstone; quartz, which is not of common occurrence, and is chiefly found where the vein is enclosed in a hard siliceous rock; and fragments of country rock, which are often enclosed in the vein. Its metalliferous constituents are galena, both fine-grained and in large facettes, both varieties being poor in silver, blende of two kinds, one compact with a brown colour, and the other fibrous, and of a yellowish hue, together with ordinary iron pyrites. Bituminous matter has been found in small nests in the Snailbeach lode, and the same substance abounds in a vein, which was worked some seventy years ago, near Pontesbury. At Snailbeach the lode even in its richest parts affords but a small proportion of massive ore, and consequently nearly the whole of the lead-producing material brought to the surface is subjected to the operations of crushing and washing. The yield of the Snailbeach mine for the year 1881 amounted to 1,946 tons of lead ore, of a value of £18,500.

CHESHIRE.—The copper mines of Alderley Edge and Mottram St. Andrews are situated in Cheshire, about four miles north of the town of Macclesfield. The escarpment or "Edge" at Alderley rises gradually from the eastern side of the plain of Cheshire towards the east, but forms an abrupt ridge towards the north. This ridge has been upheaved along the line of a large fault bearing east and west, and throwing down the Red Marl on the one side, and on the other bringing up the soft sandstone of the Bunter, capped by a wall-like escarpment of Lower Keuper conglomerate which often breaks out conspicuously from among the trees with which the side of the hill is covered. The beds rise from the plain towards the east at an angle of from 5° to 10°, and the escarpment is continued for some distance southward facing the east.

The general form of the Edge and its component beds is shown in Fig. 51, after an illustration of Professor Hull, who first determined the true horizon of the copper-bearing sandstones of this locality.[1]

SUCCESSION OF BEDS IN DESCENDING ORDER.

M. Red marl		Red and grey laminated marls.
b^4 *Waterstones*	Lower Keuper sandstone 500 feet.	Brownish flaggy sandstones and marl.
b^3 Freestone		White and brown freestone.
b^2 Copper-bearing sandstone		Soft white, yellow, and variegated sandstone.
b^1 Conglomerate		Hard quartzose conglomerate, underlain by bands of marl, forming the base of the Keuper series.
a Upper red and mottled sandstone	Bunter.	Soft, fine-grained, yellow and red sandstone, being the uppermost member of the Bunter sandstone.

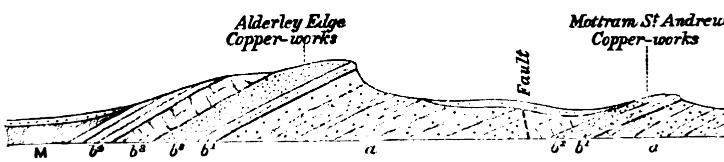

FIG. 51.—Section from Alderley Edge to Mottram St. Andrews.

The metalliferous beds are those marked b^1 b^2 at the base of the Keuper series; the former of these, besides containing ores of copper and other metals, is somewhat remarkable for its petrological peculiarities. It consists, generally, of a whitish, firmly-cemented conglomerate chiefly composed of well-rounded pebbles of quartz, in all respects similar to those which occur so constantly in the Pebble-beds of the Bunter. Copper, in the form of green and blue carbonates, is disseminated throughout the cementing material of this rock, at Alderley Edge to a very small extent only, but in considerably larger quantities at Mottram St. Andrews, about a mile to the north-east of the Alderley Edge workings. The position of the conglomerate at Mottram, so far below and beyond the base of its contemporaneous beds at Alderley, is

[1] Edward Hull, "On the Copper-bearing Rocks of Alderley Edge, Cheshire," *Geol. Mag.*, vol. i. 1864, p. 65. E. Hull and A. H. Green, "The Geology of the Country around Stockport, Macclesfield, Congleton, and Leek," *Mem. Geol. Survey*, 1866, p. 39.

due to the great east and west fault already referred to, which throws down the beds to the north. The conglomerate is here exposed in a quarry, in which, twenty-five years ago, copper was first discovered in the district. For some years systematic mining was carried on in this locality; the copper-bearing material being removed through a series of numerous shallow shafts. The results obtained were, however, commercially unsatisfactory, and the workings were therefore abandoned.

The beds formerly worked at Alderley lie above the band of conglomerate, and are marked b^2 in the section. The impregnation of copper minerals is confined to a breadth of some forty to fifty feet, in three beds of sandstone, and beyond this width the cupriferous impregnations rapidly die out on either side. The sandstone, which exhibits a uniformly soft texture, is stained along a series of imperfectly defined layers which are variously coloured green, blue, red, or brown, in accordance with the nature and state of combination of the metals present in largest quantity. In addition to copper these sandstones contain sulphate of barium and small quantities of lead, manganese, iron and cobalt. The lead is present chiefly in the form of cerussite, but galena, pyromorphite and vanadinite are also met with.

The lowest of the three metalliferous beds is sometimes as much as sixty-six feet in thickness, but it varies considerably in this respect; it dips at an angle of about 12°, and it has been worked downward for a distance of about 300 fathoms.

Above this, which is known as No. 1 bed, lies a seam of clayey sandstone varying in thickness from one foot to six feet, and upon this rests the metalliferous bed No. 2, which is 18 feet thick and covered by about twelve feet of red clayey sandstone. Above this sandstone is bed No. 3, also 18 feet in thickness, but which has not been extensively worked. The section of the beds in 1864, at the face of the workings, was as follows:—[1]

	Fathoms.
Surface clay and red sandstone	17
No. 3 bed	3
Red clayey sandstone	2
No. 2 bed	3
Blue clayey sandstone	1
No. 1 bed	11
Total	37 fathoms.

[1] G. C. Greenwell, "On the Copper Sandstone of Alderley Edge, Cheshire," *Proc. S. Wales Inst. of Engineers*, vol. iv. 1866, p. 44.

The average amount of copper contained in the workable portion of the metalliferous sandstone is about 1·4 per cent., with traces of cobalt.

These mines were worked for many years with considerable success, but the lease having expired in 1877 and the yield of copper having somewhat fallen off, the workings were suspended, and have not since been resumed. At this mine, the copper-bearing sandstone was drawn up an inclined plane, by a drum attached to the main shaft of an engine connected with a Cornish crushing mill. After having been coarsely ground, without sifting, the sand was taken to a number of tanks with perforated false bottoms, in which it was treated with dilute hydrochloric acid. Filtering rapidly through the ground sandstone the dilute acid collected in the chamber beneath the false bottom, from which it was constantly pumped and distributed over the surface of the ore. The pumping was continued until the whole of the soluble copper salts had been dissolved, the metal being afterwards precipitated by the introduction of scrap iron into the liquors drawn off into suitable receivers. The resulting copper precipitate was sold to copper smelters in the usual way.

The liquors containing ferrous chloride, from which the copper had been removed, contained a small amount of cobalt, and an attempt was made to recover that metal in the following way. The spent liquors from the precipitation of copper were run off into a large reservoir, where, after having been allowed to oxidise by exposure to the air, milk of lime was added. The precipitate thus produced contained arsenic as well as cobalt, and was smelted for speiss in a reverberatory furnace. The results obtained were, however, not satisfactory.

An attempt was also made to render available the lead ores contained in certain bands of the sandstone which, for the most part, are distinct from those yielding the bulk of the copper ores. With this view the more plumbiferous sandstones were ground between burr-stones, and subsequently washed. A very large proportion of the ore, which is chiefly cerussite, was, however, found to float away in suspension in the water, and after numerous trials it was found that the loss of lead incident on bringing the ore up to a produce of 45 per cent. was so great, that it became necessary to abandon the process.

LEAD MINES OF THE CARBONIFEROUS LIMESTONE.—The lead mines of the extreme north of England are situated in the counties of Northumberland, Durham, Cumberland, and Westmoreland. The surface of this portion of Great Britain varies in character from extensive plains to mountains of considerable height, exhibiting in some places a richly wooded and fruitful soil, while in others little is to be met with but barren hills, with more or less extensive pasturage in the valleys.

Beneath the comparatively flat land in the approximate vicinity of the eastern and western coasts the upper members of the Carboniferous series contain valuable seams of coal, and from beneath these rise the *Lead-measures*, consisting of various members of the Carboniferous Limestone. They rise gradually towards the west with an inclination greater than that of the general slope of the country, so that they successively reach the surface over a large area, attaining their highest elevation in the mountain of Cross Fell, Cumberland. Similar outcrops occur in adjacent fells, or elevated moorlands, and these, extending in a north and south direction, form the western limit of the lead-mining districts of the north.

The lofty range of elevated land constituting the Pennine Chain, extends from Derbyshire to the Cheviots, and occupies a ridge of from twenty to thirty miles in width, forming the central portion of the north of England. It sometimes attains a height of 2,000 feet above the level of the sea, and is formed of a broad anticlinal curve, which is much broken by large faults along its north-west flank towards Westmoreland and Cumberland, as well as along its western margin extending into Staffordshire. On the opposite side, throughout Yorkshire and Derbyshire, the beds are less disturbed, and usually dip at a moderate angle beneath the Coal-measures. In many parts of this range are numerous and extensive lead mines, which may be classified into the following groups:—[1]

1st.—Mining districts connected with the River Tyne, and its tributaries, the Nent, the East and West Allen, and the Derwent; namely, Alston Moor in the county of Cumberland, East and West Allendale in the county of Northumberland, and the Blanchland and Derwent Mines in the same county. In addition to these, which are distinct mining areas of considerable extent, there are other valuable lead mines situated in isolated localities, some of which are extensively worked, in the Valley of the Tyne.

[1] T. Sopwith, "On the Lead Mining Districts of the North of England," *Trans. N. Eng. Inst. Mining Engs.* vol. xiii. 1864, p. 188.

2nd.—The extensive mining district of Weardale, occupying all the upper part of the valley of the River Wear and its tributary valleys of Burnhope, Killhope, Wellhope, Treshope, Rookhope, &c.

3rd.—An extensive district in and adjoining Teesdale, the mines being situated chiefly in the valley of the River Tees, and in adjacent portions of Yorkshire and Westmoreland.

The maximum thickness in the north of England of the Carboniferous or Mountain Limestone is about 2,800 feet, which is made up of alternating strata of limestone, sandstone, and shale, while between them is interposed one thick layer of trap. The upper members of the series appear at the surface, on the sides of the upper valleys of the South Tyne, Wear, and Tees, forming the rocks in which the lead veins of those districts are enclosed. At Alston Moor, one of the principal mining centres of this part of the country, the aggregate thickness of the Carboniferous Limestone series does not exceed 1,037 feet, and consists of 183 feet of limestone, 349 of sandstone, and 505 feet of shale.

The trap rock, or *Whin Sill*, which crops out at the surface in two or three places only, may, at Alston Moor, be regarded as forming the base of the metalliferous beds; the lower portion of the Mountain Limestone is, however, visible at the surface on the western escarpment of Cross Fell.

The table on page 183, constructed by Mr. Wallace, shows the composition and total thickness of the Millstone Grit, and Mountain Limestone rocks in Alston Moor and the adjoining mining districts.[1]

In the Alston district it is unusual for any member of the series to be altogether wanting, but in the Tees-side and Troutbeck mines the strata above the Whin Sill vary considerably, both in thickness and in the order of their succession, from those found in the mines near the River Tyne. In the Tees-side district a greater thickness intervenes between the top of the Whin and the bottom of the Scar Limestone than at Garrigill on the Tyne, but in the latter the Whin is very considerably thicker than in the former, and the distance in each case between the bottom of the Whin and the bottom of the Scar Limestone is nearly equal.

The veins of the north of England may be grouped into three classes, namely, *veins*, *cross-veins*, and *quarter-point veins*.

[1] W. Wallace, "The Laws which Regulate the Deposition of Lead Ore in Veins." London, 1861, p. 17.

GENERAL SECTION OF THE MILLSTONE GRIT AND MOUNTAIN LIMESTONE ROCKS AS DEVELOPED IN THE ALSTON-MOOR AND ADJOINING MINING DISTRICTS.

No.	Local Names.	Sandstone.		Shale.		Limestone.	
		ft.	in.	ft.	in.	ft.	in.
1	Coal (Brockwell's)						
2	Slate	15	0	3	2		
3	Girdle Beds			48	0		
4	Freestone	52	0				
	Coarse Hazle Girdle Beds			37	0		
5	Millstone Grit	27	0	27	0		
6	Hard Hazle [1]	9	0	9	0		
7	Freestone	45	0	6	0		
	Grey Beds	15	0				
8	Hazle	10	6	44	6		
9	Alternating Grey Beds			88	0		
10	Grindstone Sill	24	0	33	0		
11	Hazle and Coal	9	8	10	0		
12	Fell-top Limestone					4	6
13	Hazle	12	0	30	0		
14	Do.	9	0	12	0		
15	Do.	12	0	7	0		
16	High Slate Sill	24	0	7	6		
17	Low Slate Sill	21	0	22	0		
18	Fiddler's Sill	15	0	30	0		
19	Ironstone and Coal	4	6				
20	Firestone	30	0				
	Girdle Beds			66	0		
21	Pattinson's Sill	12	0	24	0		
22	Little Lime and White Hazle	5	0	9	0	6	0
23	High Coal Sill	14	0	6	0		
24	Low Coal Sill	12	0	26	0		
25	GREAT LIMESTONE					63	0
26	Tuft	9	0	16	0		
	Limestone post					1	3
27	Quarry Hazle	30	0	37	6		
	Till Bed						
28	Four Fathoms Limestone					24	0
29	Nattrass Gill Hazle	18	0	66	0		
30	Three Yards Limestone					9	0
31	Six Fathoms Hazle	36	0	10	6		
32	Five Yards Limestone					15	0
33	Slaty Hazle	12	0	18	0		
34	SCAR LIMESTONE					30	0
35	Alternating beds { *High Copper Hazle* *Cockleshell Lime* *Low do. do.* *Post Lime* *Tyne-bottom Plate* }	35	0	90	0	14	0
36	Tyne-bottom Limestone					24	0
37	Whetstone Bed	6	0				
38	WHIN SILL	120	0	9	0		
39	Hazle	10	0	11	0		
40	Do.	11	6	3	0		
41	Do.	18	0	9	0		
42	Jew Limestone			7	0	24	0
43	Slate	15	0	4	6		
44	Little Limestone			15	0	18	0

[1] Hazles are compact sandstones.

General Section of the Millstone Grit and Mountain Limestone Rocks as Developed in the Alston-Moor and Adjoining Mining Districts—(*continued*).

No.	Local Names.	Sandstone.		Shale.		Limestone.	
		ft.	in.	ft.	in.	ft.	in.
45	Hazle	51	0	24	0		
46	Smiddy Limestone					31	6
47	Hazle	12	0				
48	Limestone			4	6	25	6
49	Hazle	12	0	5	0		
50	Robinson's Lime					21	0
51	Hazle	9	0	3	0		
52	Scar Limestone			12	0	132	0
53	Freestone	6	0	6	0		
54	Limestone					12	0
55	Freestone	105	0	9	0		
56	Do.	7	6	9	0		
57	Do.	7	6	9	0		
58	Do.	9	0	9	0		
59	Limestone					7	6
60	Hard Freestone	12	0	42	0		
61	Seven-inch Coal with Plate			129	7		
62	Freestone	30	0	7	6		
63	Limestone					18	0
64	Freestone	174	0	60	0		
	Totals	1133	2	1171	3	480	3

The first class, sometimes called *rake veins*, or *right-running veins*, comprehends all those coursing approximately east and west but varying in direction between N. 60° E. and S. 60° E. Veins belonging to this class are usually metalliferous, and are more frequently productive when enclosed in hard rocks, particularly in limestone, than when their walls consist of shale or of some other soft material.

The second class comprises all veins whose direction is nearly north and south. They usually displace those belonging to the first class, and are less variable in their course. In the strata above the Great Limestone they are rarely metalliferous, and seldom even contain any considerable amount of veinstone. In the Great Limestone they have, in the aggregate, yielded large quantities of galena, while in the strata beneath it they frequently produce ores of both lead and copper.

The veins belonging to the first two classes, which cross one another nearly at right angles, are sometimes intersected by a class of smaller veins having an intermediate bearing and hence called *quarter-point veins*, the "point" of a vein being the local term indicating its bearing. These intermediate veins traverse the country in two different directions, the one being S. 55° E. and the other S. 55° W. Like the veins of the second class they contain but little veinstone in the beds above the Great Limestone; in the strata below it, however, they are often filled with iron pyrites, copper pyrites, calcite, &c. They seldom contain lead ore.

Veins of all classes have in this district usually been formed along lines of fault. The "throw" is the term locally employed to signify the vertical disruption which generally occurs along the course of the more considerable veins. The perpendicular distance between the corresponding strata on the opposite sides of the same vein varies in Alston Moor from a few inches to 300 feet, and there is, moreover, a remarkable correspondence between the dip and throw of veins, which, although not without exceptions, is nevertheless very general.

If an east and west vein throws the strata up on its south side the dip or hade will generally be towards the north, and *vice versâ*; the dip is usually opposite the side on which the strata are highest. Mr. T. Sopwith gives the following instance of the variable throw of the same vein in different localities, as exemplified by Old Carr's Cross-vein in Alston Moor. This powerful vein throws up the strata at—[1]

Middle Cleugh Second Sun Vein	42	feet.
Middle Cleugh Vein	48	"
Carr's Vein	60	"
Broomsberry	72	"
Nentsberry Greens	162	"

In the Alston-Moor district a vein is said to be *weak* when the strata on either side are but slightly displaced, and *strong* when the difference of level between similar strata is considerable. In addition to the difference in the level of corresponding strata which so frequently occurs on the opposite sides of a vein, the veinstone itself is sometimes traversed by a longitudinal fissure with well-defined slickensides upon its faces. In the upper parts of Alston Moor, the quarter-point veins are usually small and their throw only a few inches, the largest, which is about six feet, occurring at

[1] "Mining District of Alston Moor, Weardale, and Teesdale," Alnwick, 1833, p. 107.

the Nenthead Mines. In the lower part of the field, the veins belonging to this class are much stronger, and one of them in the Rodderup Fell Mine, throws up the north-west side no less than forty feet.

The very remarkable fault known as the Great Sulphur Vein traverses the country in a westerly direction for a distance of nearly eight miles, from Hard Rigg Edge, Melmerby Fell, where it terminates against a S.W. fault, to the neighbourhood of Burnhope Seat on the borders of Durham, where it breaks up into a number of comparatively small branches which again unite near Hiddenhole Mine. Westward of this point it intersects a vein which has been worked in the Sir John Mine. After penetrating the Sulphur Vein, which was no less than 180 feet in width in this place, the miners found the Sir John Vein to have been shifted horizontally 20 fathoms. The high level on the north side of the Sulphur Vein is driven in the plate overlying the Scar Limestone, while on the south side it is in the shale under the Cockleshell Limestone, indicating a vertical displacement of about 100 feet.

A little further west the Sulphur Vein is seen on the banks of the South Tyne a little below the Tynehead Smelt Mill, which is built on the Whin Sill, through which the river has cut a narrow gorge terminating in a waterfall of about forty-six feet in height. The Whin Sill abuts against the Sulphur Vein, which on the north side throws in the Tyne-bottom Limestone, which again forms the bed of the river.[1]

This vein is mainly composed of iron pyrites in a matrix of quartz, with here and there large masses of pyrrhotine, the latter containing a small proportion of nickel and a trace of cobalt. The low level in the Sir John Mine has also been driven through the Sulphur Vein, which was found to consist of enormous masses of iron pyrites containing a little copper. Copper ore occurs in the Sir John Vein, as well as in several others in Tynehead, in strata ranging from the top of the Scar Limestone to that of the Tyne-bottom Limestone, but more particularly in the beds known as the Copper Hazles. West of the Tyne the Sulphur Vein crosses a hill called Noonstones, where it consists almost entirely of white quartz, and descending on the other side it is seen in Cross Gill, where it is said to have been at one time worked for gold. At this place the vein consists of a matrix of ferruginous quartz with patches of

[1] C. E. De Rance, "On the Occurrence of Lead, Zinc, and Iron Ores in some Rocks of Carboniferous Age in the North-West of England," *Geol. Mag.* vol. x., 1873, p. 303.

iron pyrites and pyrrhotine. Still further west it was met with in a mine at Smitter Gill, where masses of pyrrhotine may still be seen on the surface together with fluor spar and other lode stuff derived from lead veins. Many of the veins in this district when poor for lead yield hydrated oxide of iron, and, when sufficiently large, are sometimes worked for that ore. On the south side of the Great Sulphur Vein at an average distance from it of nearly a mile, the country is traversed, in a nearly parallel direction, by a trap dyke. No displacement of the strata takes place, and where opened upon by mining operations at its intersection with the Douk Burn Vein no trace of the vein was seen in the dyke, but when the latter had been cut through, the vein was found in its proper position on the other side. It therefore appears that the intrusion of the whin dyke was posterior to the formation of the metalliferous east and west veins of Alston Moor.

In addition to the three classes of veins before described, large quantities of lead ore are sometimes obtained from *flats*. Veins, however irregular may be their width, have usually walls or cheeks which maintain the fissure-like character of the opening. In certain members of the lead-bearing strata in this district, however, and especially in the Great Limestone and the Scar Limestone, the veins sometimes branch off laterally into flats which are often very productive. These flats vary as much in their size and characteristics as do the veins themselves. When in the region of flats the miner sometimes cuts into caverns of varying extent, either lined with crystals of calcite, blende, galena, &c. or filled with clay or veinstone. An opening often connects such flats with a vein, and under those circumstances they frequently produce large quantities of ore. Occasionally flats extend over considerable areas and terminate suddenly at a *back* or joint in the strata. Flats situated at a distance from a large vein have often numerous strings or *leaders* running into them; this term being applied by miners, because by following them they are often led to the flats themselves.

The minerals most frequently occurring in the lead veins of this region are quartz, calcite, iron pyrites, blende, galena, fluor spar, and sulphate of barium. In the strata included between the Grindstone Sill and the top of the Little Limestone, the amount of quartz deposited in the veins is less than might have been expected from the generally siliceous nature of the rocks; fluor spar, calcite, and oxide of iron being the prevailing minerals.

In the Little Limestone of the Nenthead district the veins frequently contain much blende and iron ore, and a greater proportion of quartz than is usually found in the sandstones above. Calcite and fluor spar are occasionally met with in this limestone and in the Coal Sills below. Blende is commonly accompanied by quartz, although the converse does not follow, since veins almost filled with this mineral often contain no sulphide of zinc.

In the veins in the Great Limestone a greater variety of minerals is found than in those of any of the strata above. Fluor spar is, however, rarely met with in any considerable quantity in the Nenthead Mines, although it must have been at one time tolerably abundant, as pseudomorphs in quartz after fluor spar are by no means uncommon.

At Garrigill, calcite and fluor spar occur abundantly in the Great Limestone, the veins being in many places almost filled with these minerals. In the Weardale and Allenhead districts the veins in all the strata are chiefly filled with galena, calcite and fluor spar.

In the sandstones below the Great Limestone the east and west veins generally contain more quartz than they do in the strata above. Both the right-running veins and the north and south veins contain much imperfectly crystallized quartz in the Scar Limestone. The veins which have been worked for lead in the Tyne-bottom Limestone often contain much calcite, although quartz is by no means uncommon. In the flats in this limestone beautifully crystallized calcite occurs.

In the Tyne-bottom mines some of the veins have been partially explored in the Whin Sill, where they were found filled with calcite and spathose iron ore, but containing no galena.

The principal veins of the north of England divide the whole of the strata of the Carboniferous Limestone series, which are brought variously in opposition to one another by the dislocations usually accompanying vein fissures in that region. Instances have from time to time been recorded of veins being productive under almost every possible circumstance of opposition of the strata, but certain beds have nevertheless long been favourably known for their richness in lead ore. In different mining districts different limestones are thus favourably distinguished, but in the country around Alston Moor, Teesdale and Swaledale, the Great Limestone is by far the most productive stratum.

In confirmation of this, the following extract relative to the actual quantities of lead ore obtained from all the beds in the manor of Alston Moor, during the year 1822, is given from Mr. J. Taylor's Report on mineral veins :—[1]

Limestone Beds	Great Limestone	20,827 bings[2]	
	Little Limestone	287 "	
	Four-fathom Limestone	91 "	
	Scar Limestone	90 "	
	Tyne-bottom Limestone	393 "	
			21,688 bings
Gritstone Beds	High Slate Sill	107 bings	
	Lower Slate Sill	289 "	
	Firestone	262 "	
	Pattinson's Sill	259 "	
	High Coal Sill	327 "	
	Low Coal Sill	154 "	
	Tuft	306 "	
	Quarry Hazle	44 "	
	Nattrass Gill Hazle	21 "	
	Six Fathoms Hazle	576 "	
	Slaty Hazle	18 "	
	Hazle under Scar Limestone	2 "	
			2,365 bings
	Total		24,053 bings

With regard to the origin of the lead deposits of Alston Moor, Mr. Wallace observes "it would appear that either lead in connection with some basifying principle must enter, in varying proportions, as a component part of the rocks of this district, or some still more elementary substances from which it is formed by laws of chemical combination as yet unknown. I am not aware that the limestones and sandstones of Alston Moor have ever been subjected to careful chemical investigation. If from their analysis it is proved that lead is diffused throughout their whole mass, then the inquiry would be much simplified, and chemists would be able to demonstrate the changes which must be effected in order that sulphide of lead may be deposited in the veins by the agency of circulating waters."[3]

The four most northern counties of England produced, respectively, the following amounts of lead ore, lead, and silver during the year 1881 :—[4]

	Lead ore. Tons.		Lead. Tons.	Silver. Oz.
Northumberland, Durham	17,467	=	13,089	54,036
Cumberland	2,376	=	1,720	13,786
Westmoreland	1,236	=	904	11,954

Cumberland also produces annually about 1,800 tons of zinc ores.

[1] *Report Brit. Association*, 1833, p. 1.

[2] Each weighing 8 cwts.

[3] "The Laws which Regulate the Deposition of Lead Ores in Veins," 1861, p. 242.

[4] R. Hunt, "Mineral Statistics for 1881," *Memoirs of the Geol. Survey*, 1882.

The lead-mining district of Yorkshire includes an area of about 700 square miles, and comprehends the high ground bordering Swaledale, Arkendale, and Wensleydale in the north, and Nidderdale, Wharfedale, and Airedale to the south. The rocks of this area, like those of the lead-bearing districts further north, belong to the Carboniferous Limestone period, but although they prevail throughout the whole mining area, each individual stratum is by no means everywhere represented, and the thickness of the different beds is exceedingly variable.

The lead ore of the Yorkshire mines is derived from rake veins, pipe veins, and flats. Of these the rake veins are the most productive and important; their course does not usually vary materially from a straight line, but their dip is far from constant. Their inclination from the horizon is less in soft argillaceous beds than in hard solid rocks; while, when passing a thin seam of shale, or soft clay, they often flatten and follow for a considerable distance the inclination of the strata. As is the case elsewhere, the width of the Yorkshire veins is exceedingly variable, frequently opening from one or two feet to several yards, and again contracting to a mere joint. The width of a vein is usually affected by a change of strata, and is greater in hard rocks than in soft ones; it is generally greater in limestone than in sandstone, and in the latter rock than in shale. Rake veins are, in the majority of cases, fault veins, the strata being as a rule lower on the side of the dip than in the contrary direction.

The extent of the throw varies from a few inches to twenty or thirty fathoms; the greatest amount of throw being often observed when nearly parallel veins are in the almost immediate vicinity of one another. The *strength* of a vein is considered to be in direct proportion to the extent of its throw. A vein with a difference of from six to eighteen feet between the height of similar beds on the two sides, is regarded by the miner with more favour than one with either a greater or less displacement. A fault of this extent is looked upon as an indication that a vein has sufficient strength to insure its size and continuity, but is not so great as to destroy the effect supposed to be produced by certain beds when occurring on the same horizon on both sides of a vein. When rocks of a different character form the opposite sides or cheeks of a vein, a deposit of lead ore is rarely found between them; this rule is, however, not without exceptions. At the Grassington Mines, in Wharfedale, there are two veins each throwing the strata, south side down, to such an extent as to cause shale to be opposed to gritstone, shale to limestone, gritstone to limestone, &c., and so on throughout their whole explored depth. Under these conditions one of the veins yielded large quantities of ore, while its neighbour proved totally barren.[1]

When a vein occasions a throw of from two to three fathoms, the ore seldom continues either above or below the change of strata, but is confined to those portions of the fissure which are bounded by the productive rock. An exception to this rule occurred, however, at the Grassington Mines, where a vein produced large quantities of lead ore for considerable distances both above and below such a change of strata. In addition to causing a fault or throw, rake veins materially influence the dip of the strata in the immediate vicinity of their walls. On the side of the more elevated beds the planes of stratification are, for a short distance from the wall, bent downwards, while those on the opposite side are, on the contrary, bent upwards.

Although the veins of this county traverse all the beds of the Carboniferous Limestone, there are only certain members of it that usually yield lead ore. In some districts the most abundantly productive strata are limestones, while in others the larger proportion of lead is obtained from the sandstones. The argillaceous shales very rarely produce ore, but even this admits of exceptions, since in the Airedale district lead ores have sometimes been found in these rocks. The great Whin Sill extends into Northern Yorkshire. In the more northern districts many of the veins have a nearly direct course over a considerable distance. The Old Gang Vein in Swaledale, which has been worked over a length of some miles, and which can be traced in a nearly straight line for a still greater distance, is an example of this persistency of character in lead veins.

The veins of the three northern districts, namely, Swaledale, Arkendale, and Wensleydale, are more regular in size, and the beds more uniform in thickness than they are in the more southern areas. In the former the limestones have been the principal sources of production, while the ores of the southern mines have been chiefly derived from sandstones. Many peculiarities distinguish the mines of the northern districts of Yorkshire from those of the south, and divide them into two distinct classes. Rake veins, pipe veins, and flats are common to both, and it is to be remarked that, on account of the composition of the veinstone with which they are associated, ores from pipe veins and flats

[1] Stephen Eddy, "On the Lead Mining Districts of Yorkshire," *British Association Reports*, 1858, pp. 167–174.

are more fusible than those from rake veins. The ores from the limestones are also more easily worked than those from sandstones.

It has been asserted that slickensides never occur in the sandstones of the Yorkshire lead mines, but this is not absolutely correct, since in the Grassington Mines a slickenside was met with in that rock, where, for a distance of nearly seventy yards, it formed the only division between two veins. In both areas, the majority of the lodes are nearly parallel to one another, while the remainder run counter to them and form intersections.

The predominant direction of the principal veins is, in the northern mines, north of east and south of west, while in the southern field it is north of west and south of east. The former, known as right-running veins, are, when intersected by the cross-veins, frequently heaved or otherwise affected. In such cases the heave is usually on the side of the oblique angle formed by the intersecting planes of the converging veins. When one or both of the veins have been productive of ore up to the point at which they come together, their yield is, in the majority of cases, increased by their junction. The extent of the angle formed by two veins is, however, regarded by the miner as of much importance, since he considers an acute angle as indicating riches, while a large one is believed to be an unfavourable indication.

Nearly one half of the present annual production of lead ore in Yorkshire is obtained from Arkengarth Dale, but East Craven Moor, Keld Heads, and Old Gang are still among the productive mines. The total yield of the Yorkshire mines during the year 1881 amounted to 4,171 tons of lead ore, equivalent to 3,040 tons of lead, and 4,115 oz. of silver.

The Carboniferous Limestones of Derbyshire rise to the surface over large areas, and are deeply cut into by numerous picturesque valleys, but the base of the series is nowhere exposed. The total thickness of the rocks of this age is about 1,500 feet, and instead of there being one bed of intruded trap, as in the northern counties, there are here three distinct beds of an igneous rock, locally known as *toadstone* or *todtstone*, interpolated between four thick beds of limestone.

According to Mr. Wallace, the series of beds comprehended between the top of the Great Limestone and the Grindstone Sill in Alston Moor, corresponds with the Limestone Shale of Derbyshire, the thickness of the two being nearly the same; on the other hand the Millstone Grit, which is fully developed in Alston Moor, will correspond to the Grits of Derbyshire and Wensleydale.

The mineral deposits of Derbyshire comprehend rake veins, pipe veins, and flats, besides which cross-fissures in the limestone, known as *scrins*, sometimes enclose small quantities of lead ore. Few veins are metalliferous either in the Millstone Grit or in the shales, the great majority being profitably worked in the limestone only. When a lode reaches the toadstone it usually either ceases entirely, or passes through it as a narrow cleft containing no ore. In the limestone beneath the toadstone a vein is sometimes found to have resumed its original condition, but, generally speaking, the workings of the smaller mines are exclusively confined to one bed of limestone.

In 161 out of 180 observed cases, the lode is stated to have entirely disappeared in the toadstone, while in nineteen cases the vein passed through it. As B. v. Cotta however remarks, these results cannot be regarded as altogether reliable, since, from the point of view of a practical miner, a vein which passed through the trap in the form of an unproductive fissure would probably be regarded as having ceased to exist. The prejudicial influence often apparently exercised by this rock upon the production of lead veins, at one time regarded as acting almost universally, has more recently been found not to be without important exceptions. The Mill Close Mine in Darley Dale, which has for some years been the most productive in the county, is worked between shale on one side and toadstone on the other. Some of the rake veins, however, throw the strata, and in such cases it would appear that the vein fissure must have divided all the beds including the toadstones. In some instances the veinstone itself is found divided longitudinally for considerable distances, with the contact surfaces often highly polished. These slickensides are ribbed or slightly fluted horizontally, and sometimes after one side is removed, so as to give room and relieve pressure, fragments fly off, occasionally with loud explosions, and continue to do so for many days.[1] The toadstone, of which there are three beds, is a dark, compact rock, sometimes closely resembling basalt, but more commonly softened by decomposition, and often presenting an amygdaloidal structure.

Each of the beds averages from sixty to seventy feet in thickness, and preserves its course between the strata of limestone for many miles uninterruptedly. It is somewhat doubtful whether these layers of igneous rock are to be regarded as lava-flows contemporaneous with the deposits of limestone, or as subsequent

[1] "General View of the Agriculture and Minerals of Derbyshire," by John Farey, Sen. London, 1811, vol. i. p. 250.

injections into fissures parallel with the stratification. De la Beche regarded them as contemporaneous flows; Sedgewick, on the other hand, believed them to be subsequent injections. Jukes pointed out that each of them is probably the result of not merely one eruption, but rather consists of different flows proceeding from distinct vents and uniting into one sheet along a common floor. The most productive mines have been worked in the First Limestone, and perhaps the least so in the fourth stratum of that rock, which does not, generally speaking, appear to carry any large amount of ore.

The production of lead ore in Derbyshire in 1881 amounted to 3,834 tons, equivalent to 2,875 tons of metallic lead. These ores are exceedingly poor for silver. The Mill Close Mine yielded during 1881 more than one-third of all the lead produced in the county. Four others afforded from 265 to 545 tons of lead ore each; the balance having been made up by the yield of above forty small mines.

The celebrated copper mines of Ecton [1] are situated on the borders of Staffordshire and Derbyshire. The principal deposit, which as early as the year 1778 had been worked to a depth of 200 fathoms, is a pipe vein, piercing the highly-contorted limestone beds almost vertically. There are eight main lodes coursing E. and W., and the same number of N. and S. veins, together with many smaller branches. The upper portions of the lodes contain galena, poor in silver, and blende with copper ores; the latter predominating in the lower levels. The principal ores are chalcopyrite and erubescite, and with these occur oxides and carbonates. The vein stuff is composed of very transparent calcite, which is sometimes of a bright yellow colour, colourless or bluish fluor spar frequently enclosing crystals of chalcopyrite, barytes, chalybite, iron pyrites, and calamine. The veins sometimes attain a great thickness; being in one case as much as seventy yards from side to side. From an historical point of view the Ecton Mine is interesting, as it was here that blasting was first introduced into England. Bishop Watson [2] states that he had seen the smithy in which the first borer ever used in England was made, and that the first shot fired was in the Ecton Mine. This borer must have been made for the German miners whom Prince Rupert brought over in 1636 to work the mine, and traces of whose work may still be seen in the so-called "Dutchman's" adit.

[1] W. Pryce, "Mineralogia Cornubiensis," 1778, p. 81. J. Mawe, "Mineralogy of Derbyshire," 1802, p. 109.

[2] "Chemical Essays," 1781, vol. i. p. 332.

From 1760 to the end of 1768, namely, eight years, the Ecton Mine yielded 5,862 tons of copper ore worth £57,494 8*s.* 1*d.* From March 9th, 1776, to December 27th, 1817, 53,857 tons 13 cwts. of ore were raised, containing copper of the value of £677,112 14*s.* 3*d*, and yielding a net profit of £244,734 11*s.*[1] The ore appears to have generally yielded a produce of about 15 per cent. of copper.

WALES.

IRON ORES.—The production of red hæmatite in South Wales is very small, since at the present time there appear to be no mines working upon this ore. Some years ago a deposit of this mineral was opened at Cwm Mountain, in Flintshire, at a short distance from the famous lead mine of Talargoch. The ore here occurs in the form of a breccia composed of angular fragments of hæmatite, cemented together by crystalline calcite stained a brick-red colour by diffused oxide of iron. This ore, which is found in irregular pockets in the Carboniferous Limestone, is accompanied by brown hæmatite, which occasionally assumes the form of octahedral crystals, probably pseudomorphs after magnetite.

An oolitic variety of calcareous red hæmatite occurs in the Lower Limestone shales at Whitchurch, in Glamorganshire, but on tracing the bed for a short distance either in an easterly or westerly direction, it is found to become gradually changed into an encrinal limestone. The Coal-measures of South Wales are naturally divided into two series, the upper and the lower. These are over the whole area of the field separated from one another by hard siliceous beds, which sometimes pass into conglomerate, and are locally known as the *Cockshute* or *White Rocks.* The hardness of these beds, together with the large amount of water which they contain, always presents formidable obstructions to sinking through them. The upper series contains but little iron ore, although the lower one, sometimes called the *Iron-bearing Measures,* comprehends numerous valuable deposits of clay ironstone. At its eastern outcrop the coal of the lower measures is bituminous, but gradually changes its character when followed in a westerly direction, until, after passing the great fault of the Vale of Neath, it becomes true anthracite. The coals of the upper series are everywhere bituminous, even when anthracite is found in the beds below. The rocks in which the coal and ironstone of this series are imbedded are known as the *Pennant Rocks.*

[1] Statement furnished by Mr. R. Taylor.

The lower or iron-bearing measures extend over the whole coal-field, and the principal beds of ironstone are found in the lowest strata. The ironstone is usually richest towards the eastern boundary of the field, but, although the yield of iron is less considerable, the thickness increases in going west. Near the eastern extremity of the basin, which is the great iron-producing district of South Wales, the southern outcrop dips very rapidly, while the dip of the more northern is less considerable. The highest part of the basin in which ironstone has been profitably worked is a bed of blackband occurring on the top of the Mynyddysllwyn seam of coal. This ironstone, like that which receives the same name in Scotland and North Staffordshire, contains a sufficient amount of carbonaceous matter to effect its calcination without any additional fuel. The bed, although irregular, is sometimes several feet in thickness, and occurs as a series of unconnected basins. The next ironstone bed occurs over the coal, known on the north outcrop at Dowlais as the Old Man's Coal or Gŵr-hyd Coal, while at Abercarn and Risca, on the southern outcrop, it receives the name of the Charcoal Seam and Rock Vein respectively. This is also a seam of blackband, and is worked at Abercarn under similar conditions to the Mynyddysllwyn bed; considerable quantities of this ore, which works well in the furnace, have been raised. These irregular beds are the only seams of ironstone that have been worked in the upper series.

The lower series contains so many strata of ironstone alternating with coals and shales that it would be impossible even to notice all of those which have been more or less worked; many of them are not persistent over the whole field, and consequently vary in thickness within comparatively short distances.[1] Many of the ironstones, however, exhibit a marked similarity both in structure and composition throughout a large portion of the district, and there can be little doubt that some of them exist as continuous beds. The Three-quarter Balls, which in all the eastern parts of the coal-field are traversed by numerous fissures containing quartz, calcite, spathose iron ore, millerite and hatchettine, may be quoted as an example. The ironstone measures of South Wales are exceptionally regular and well developed near Ebbw Vale, where they are extensively mined, as they are also at Blaenafon, Pontypool, Abercarn, Dowlais, &c. These ironstones in their raw state contain from twenty-one to thirty-eight per cent. of metallic iron, in addition to which traces of copper, lead, and even

[1] "The Iron Ores of Great Britain," *Mem. Geol. Survey*, part iii., South Wales.

silver, are sometimes present. The annual production of ironstone from the Coal-measures of South Wales is about 170,000 tons, but very large quantities of hæmatite and other ores are imported from Whitehaven, Lancashire, and elsewhere, for supplying the iron-works of the district.

In South Wales the lower beds of the Permian series sometimes occur as hæmatite, but such deposits are of a local character only, and are usually found in basin-like hollows. One of these basins, opened some years since at Mwyndy, near Llantrissant, has yielded large quantities of ore, and had evidently been extensively worked at some long past and forgotten period, since numerous old workings, together with tools and other relics, were discovered in re-opening the mine. A similar deposit occurs at Gwar Coch, about two miles north of Porth Caul. It overlies the limestone, and sometimes contains as much as 35 per cent. of oxide of manganese, thus almost giving it the character of a manganese ore.

According to the returns of the Mining Record Office, South Wales produced no hæmatite ores in 1881, but during that year the production of brown iron ore in South Wales and Monmouthshire is stated to have been 81,372 tons.

Cardiganshire and Montgomeryshire.—The metalliferous district of Cardiganshire and Montgomeryshire consists of a tract of clay slates and gritstones, chiefly of Cambrian age, extending for a distance of about forty miles in a N.N.E. and S.S.W. direction, and varying in width from five to twenty-two miles.[1] Large areas in this district do not appear to contain mineral veins, and those which do so, and which are known to be productive, are usually characterised by some lithological peculiarity of their rocks. No rocks of igneous origin are found in any portion of this region, and the occurrence of the lodes in beds belonging to one epoch only, renders it impossible to fix their geological age with any degree of accuracy. Moreover the direction of the lodes affords no clue for the determination of their relative ages, since, however different may be their strike, no decided difference can be observed in their filling, neither is there, on the other hand, any such evidence of the passage of one through another as would allow of their being thereby classified into groups. The appearance of the outcrop of the veins of this district is usually devoid of such marked characters as would attract the attention of those accustomed to find gossans resulting from

[1] W. W. Smyth, "On the Mining District of Cardiganshire and Montgomeryshire," *Mem. Geol. Survey*, vol. ii. part ii. 1848, p. 655.

the decomposition of pyritous ores. A large preponderance of slaty matter is frequently to be observed in the lodes of this district. Its whole area consists of a succession of rolls or undulations of beds which, in the main, belong to the same series, but which vary in character from soft shales, through many varieties of slate, flag, and argillaceous rock, to coarse gritstone and conglomerate. The zones in which the productive mines are situated lie approximately parallel to the axes of the several undulations referred to, and by imagining lines of division to run in the same direction, the veins of the district may be classified into six groups, which, although to some extent chosen arbitrarily, exhibit in many respects distinctive characters, and afford a means of consistent classification.

The first group of this district, beginning on the west, borders on the unproductive grits of Aberystwith, and includes the once celebrated mines of Tal-y-Bont, Penybontpren, Llancynfelyn, and Tre'rddol, yielding lead ores containing a very small proportion of silver, together with blende and occasionally a little copper pyrites. The lodes are usually small, and frequently intersect a fissile variety of slate, in which, throughout the whole of this district, they are rarely productive.

The second group of veins, which is of greater importance, was two centuries ago known as the "Welsh Potosi," and returned enormous wealth to the adventurers then working them. The slaty rocks here assume a paler tint, and present a peculiar silky lustre; their bedding is more massive, and the width of the veins much greater, being in some cases upwards of twenty feet. This ore is usually argentiferous, and the lead obtained from it sometimes contains as much as thirty-eight ounces of silver per ton.

The third division, ranging from Ystrad Meyric to the Devil's Bridge and along the course of the Rheidol, comprehends a number of metalliferous veins, varying in character almost as completely as do the rocks which they traverse. Thus the Llwyn Malys Lode is remarkable for the proportion of silver contained in its ores, Fron Goch for its large deposits of galena and blende, and the Estymteon Lode for its iron pyrites. The outcrops of others occasionally afford ores of manganese, while the country rock varies between gritstone, dark fissile slates, and an indurated argillaceous rock of a grey colour, in which the productive lodes of the district generally occur.

The fourth band, striking from Llampeter to the central range of Plymlumon, includes the highly argentiferous lead lode of Llanfair Clydogau, while some miles to the north are various lodes productive of common lead ores, associated with blende and calcite.

The fifth metalliferous band, ranging along the east of the Plymlumon ridge, comprehends the mines of Cwm Ystwyth, and different veins worked in the upper valleys of the Wye and Severn, as well as the more important works of Delife and the group of parallel lodes near Llanbrynmair. Beginning with the elevated mass on which the Teifi pools are situated, the southern part of this division is characterised by frequent intercalations of arenaceous matter, which to the north are succeeded by argillaceous shales. It is remarkable that, while throughout the former area copper pyrites is so common a constituent of the lodes as to be separately returned from several of the mines therein situated, in the latter it is but seldom found.

The sixth division, although circumscribed on the east and north by the gritty beds cropping out from beneath the Wenlock Shales, comprehends a few mines in the neighbourhood of Llanidloes, which are remarkable from the lead being accompanied by witherite and heavy spar, neither of which minerals are known to occur in any other part of the district.

In the same zone might be included another group of lead veins situated in the part of the district around Llangynnod, at a distance of nearly thirty miles from the lodes above mentioned. These last traverse slaty rocks, and the ores of lead and zinc which they afford are often associated with witherite and heavy spar. The country rocks however differ, inasmuch as that beds of porphyry and of various crystalline rocks of volcanic origin are intercalated between the slates.

The most general strike of these lodes is E.N.E. and W.S.W. Although this direction is for short distances subject to frequent variations, nearly all the most important deposits agree within a few degrees with this course. The dip is most frequently towards the south, generally varying between 60° and 80° from the horizon. In some cases however the inclination is in the contrary direction, and the occasional flattening of the angle is not found in so marked a manner as, in some mining districts, to cause a diminution of the productiveness of a lode.

The filling material of the vein fissures in this part of Wales is for the most part slate in angular fragments of all sizes, from the most minute particles to large masses sometimes fathoms in length and height, forming horses which split the lode into two or more distinct branches. Its most common associate is quartz, and upon the structure and colour of this, the miner, to a large extent, bases his opinion of the probable value of the lode; in doing this he makes a distinction between opaque massive quartz and the drusy cellular and sometimes granular varieties which usually accompany deposits of ore. Calcite occurs in small quantities only, and fluor spar, which elsewhere is so common an attendant of lead ores, is here entirely unknown. Galena is met with in the mines of this district crystallized either in cubes or octahedra, or in combinations of the two forms, and it is to be remarked that the argentiferous varieties are as often well crystallized as those which do not contain silver.

Cerussite is sometimes found as a product of decomposition on the outcrops of a few lodes only. Blende is frequently more plentiful than galena, but calamine has not been found in any considerable quantities excepting in the Nant-y-Creiau Mine. Copper pyrites in irregular spots, is often mixed with the galena, and iron pyrites, which is sometimes sprinkled in the form of cubes throughout the slate rock, is found abundantly in the lodes of this district. Chalybite is met with in the form of branches in the vicinity of some of the veins, and an ore of manganese has been obtained from old workings on the Drosgol hill, near Rheidol; it is, however, an impure hydrous oxide of but little commercial value.

The various minerals filling the veins of these counties are rarely disposed with such regularity as to lead to the conclusion that the deposition of one substance had ceased before that of another had commenced; they usually occur in strings and spots which are sometimes parallel for short distances, but they more frequently ramify in an irregular manner, and often form a network of branches. Generally, however, it may be observed that the calcite takes the inner side of the quartz, whether occurring in drusy cavities or in ribs, and galena appears to occupy an analogous position with regard to blende. A structure of this kind, varying constantly in its details, exhibited by the Estymteon lode, is represented in Fig. 52, in which *a* is copper pyrites, *b* quartz, *c* blende, *d* iron pyrites, and *e* galena.

When a deposit is of considerable thickness the metalliferous portion of it frequently exhibits a tendency to form in bands, and wherever one of these becomes wedged out, another, and nearly parallel stripe, commences, forming a *splice*, as shown in Fig 53, in which *a* and *b* represent two separate and nearly parallel masses of ore which form a splice with overlapping ends. As before mentioned, the structure of the veinstones of this part of Wales is frequently brecciated, angular fragments of slate being united by a cement consisting either of quartz, galena, or blende, while more rarely, a ground-mass of calcite encloses angular pieces of galena, chalcopyrite, or blende.

Cross-courses, generally filled with clay, but sometimes appearing as mere partings in the rock, are not unfrequent, and occasionally heave the lodes for a distance of several feet; they are, however, less common than in many other mining districts. The country

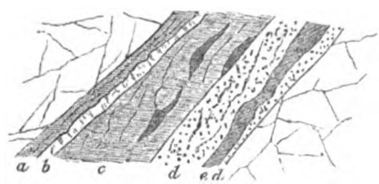

FIG. 52.—Estymteon Lode; section

rocks on the opposite sides of many of the lodes have been affected by unequal movements resulting in the displacement of one or both of the walls; but, from the absence of easily recognised beds, it becomes difficult to measure any change of level which may have taken place.

Numerous facts have been observed with regard to the ore-bearing portions of these lodes which are in perfect accordance with the experiences of other districts. Thus when two lodes approach

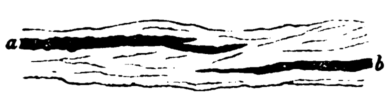

FIG. 53.—Vein forming a splice.

one another under a small angle, their junction is usually marked by an expansion of the deposit of ore, and a similar effect is produced when branches or short veins fall into the principal lode; the effect being the same whether this falling together of the branches takes place along the line of strike or on that of the dip. The same result is observed in a greater degree where two or more lodes become united into one. The productive portions of the lodes are generally more continuous in their vertical than in their horizontal range, and they have most frequently an inclination towards the west. From this circumstance it might be inferred that they run parallel to the bedding of the more metalliferous rocks, but Mr. Smyth is inclined to believe that they more frequently conform to the planes of cleavage of the country rock than to those of its bedding. The lead veins of this part of Wales differ materially from those of Cornwall in one important point, namely, that whenever they pass from a harder to a softer rock their mineral contents decrease in quantity.

In the year 1881, the most important operations carried on in Cardiganshire were those of the Lisburne Mines, which produced during that year, 1,005 tons of lead ore, and 3,550 oz. of silver. The most productive mine of Montgomeryshire during the same period was the Van, yielding 2,600 tons of lead ore, 1,400 tons of blende, and 23,400 oz. of silver.

MERIONETHSHIRE.—This county comprehends no extensive or largely productive metalliferous areas, but is remarkable, inasmuch as that some of its rocks enclose veins which have been long known to be auriferous. The gold-bearing district would appear to be mainly confined to about twenty-five square miles of the country lying on the north of the turnpike road leading from Dolgelly to Barmouth. In this district the Cambrian rocks are overlain by others of Silurian age, and about half way between the two places, a stream which descends from the higher range of Llawllech discharges its waters into the Mawddach river below Pontddu. On either side of this rivulet rises a mountain, one being the Vigra and the other the Clogau, in both of which copper mines have been worked intermittently for many years. Among the mines which at one period attracted the greatest amount of attention are the Vigra and Clogau, the Dol-y-frwynog, the Cefn Coch, and the Prince of Wales.

So long ago as the year 1844, a paper was read before the British Association by Mr. Arthur Dean, who stated that a complete system of auriferous veins existed throughout the whole Snowdonian region of North Wales. In consequence of this and of equally sanguine statements made by others, mining operations were shortly afterwards commenced at Cwm Eisen, but the results obtained being unsatisfactory, the mine was abandoned. About two years subsequently to this, machinery for crushing and amalgamation was erected at Dol-y-frwynog, but the treatment of several hundred tons of veinstone having resulted in the production of only a small amount of gold, the operations were suspended.

Among the auriferous veins which have from time to time been worked in North Wales, that opened in the Clogau Mine has been by far the most productive. At Clogau the workings have been exclusively conducted upon the St. David's, or Gold Lode, which is situated nearly a mile further north than that formerly worked for copper. At a short distance north of the St. David's Lode, the massive greenish grits of the Cambrian system emerge from beneath highly inclined beds of Lower Silurian age. The vein, which courses nearly E. and W., is often from two and a half to nine feet in width, and commonly lies between two distinct walls, especially on the southern side; it is usually almost perpendicular, but sometimes dips slightly towards the north.

It is chiefly composed of quartz and calcite, the latter mineral sometimes forming masses of several feet in width; where the calcite assumes the appearance of a friable and granular marble, it not unfrequently contains gold, but when, on the contrary, it becomes foliated or is coarsely granular, that metal appears to be entirely wanting. Spots of iron pyrites and chalcopyrite are frequently scattered through the veinstone, which circumstance caused the vein to be originally regarded as a copper lode. Fragments of the country rock are often included in the vein, and a few yellowish metallic points and crystalline spangles and plates of gold are sometimes disseminated in the lode. With the gold is not unfrequently associated the compound of tellurium, bismuth and sulphur, known as tetradymite, which occurs in crystalline scales of silvery whiteness and of brilliant metallic lustre.[1] The laminæ of the country rock on either side of the lode strike only a few degrees more to the N. of E. than the lode itself, and they are consequently intersected at so small an angle that in places where the lode is somewhat obscure it occasionally requires care on the part of the miner to prevent turning off into the country rock. Another noticeable feature of this vein is the frequent occurrence of nearly horizontal planes of division crossing it from one side to the other. In width the St. David's Lode is even more than usually variable, for although, as before stated, it is sometimes nine feet in width, at others it is reduced to a mere fissure.

The experience acquired from the working of this and other gold veins in North Wales goes to show that the only remunerative material is that small proportion of the lode which contains

[1] W. W. Smyth. "Gold Mining at Clogau, North Wales," *Mining and Smelting Magazine*, vol. i. 1861, p. 359.

visible gold, and that this is not usually present in sufficient quantities to pay the expenses of mining &c.; several rich bunches of gold quartz have, however, been found in the St. David's Lode, and for a short time the Vigra and Clogau Mines were, on a comparatively small scale, very profitable.

The total weight of gold, of an average value of £3. 4*s*. per oz. obtained in North Wales from the end of 1844 to April, 1866, is estimated as follows:—

	Oz.
Old Dol-y-frwynog	117
Prince of Wales	63
Cwm Eisen	176
Gwyn-frwynog	6
Cefn Coch	478
Castell Carn Dochan	182
Vigra and Clogau	11,778
	12,800

Only a very small quantity of gold has been obtained from the Welsh mines since 1866. Mining operations have, however, been for some years carried on at Clogau with the view of reaching the St. David's Lode at a greater depth than any at which it had been hitherto worked. Shortly after the intersection, in 1881, of the lode by this deep cross-cut, it was understood that about 225 oz. of gold had been obtained from a level driven upon its course, but no announcement of any further discovery has been recently made.

In the Mawddach valley, a little below Tyn-y-groes, but on the other side of the river, is the Glasdir Copper Mine, where the ore instead of being contained in a lode, is disseminated in an altered slaty rock. The iron pyrites and chalcopyrite which here occur are found in the vicinity of the branches of an eruptive felspathic rock which has broken through the slate in all directions. When prepared for market this ore yields only a small percentage of copper, but contains a little silver, and from one to one and a half ounce of gold per ton. The annual returns from this mine were very inconsiderable.

FLINTSHIRE AND DENBIGHSHIRE.—In this mining area a long series of parallel veins course across the Mountain Limestone into the Millstone Grit, and are, further east, only observable as faults in the Coal-measures. These veins are intersected by a system of strongly marked cross-courses, which are traceable for many miles in length. They are usually barren, but exceptionally, as in the neighbourhood of Holywell, they have afforded large quantities of lead ore. In former times almost fabulous amounts of lead were obtained from these mines, the galena having been frequently found in a state of purity and solidity not often equalled elsewhere. When unproductive, these veins are usually filled either with opaque calcite or with plastic clay, and the operations of the miner are often impeded by an unusually large influx of water. The most remarkable mines of this district have been Talargoch, near Rhyl, and Minera, six miles north-west of Wrexham.

Many of the lead mines in this district, and particularly some of those in the neighbourhood of Mold, have been remarkable for the large quantities of white lead ore, cerussite, which they have yielded when the veins intersect the sandstones of the Millstone Grit. Large quantities of this ore have also been obtained from pipe veins which had evidently been cavities produced by the action of water, and subsequently filled with various mineral substances brought into them in a state of solution.

Minera, which was not long since the most productive lead mine in Great Britain, occupies a considerable portion of a patch of Mountain Limestone which has been disrupted by faults from the southern extremity of the mining area of Flintshire. On the northern side there is a downward displacement, while on the southern there is a throw towards the east. The sett comprehends portions of the Coal-measures and of the Millstone Grit together with certain underlying Silurian rocks.

The Mountain Limestone of this district rests unconformably upon Lower Silurian strata, but somewhat further south, thin sandstones and slates of Devonian age are interposed between the limestone and Upper Silurian shales. The Carboniferous Limestone is here usually overlain by Millstone Grit varying in thickness from 30 to 200 feet, and this is occasionally covered by true Coal-measures; while in some places the Millstone Grit is entirely absent and the Coal-measures rest immediately on the limestone. These different strata are frequently much disturbed, and afford examples of almost every description of mineral vein varying from true lodes to thin branches and strings of ore, generally destitute of veinstone.[1]

Two principal lodes are worked in this mine, namely, the Old

[1] George Darlington, "Mineral and Geological Sketch of the Minera Mining Field," *Mining and Smelting Magazine*, vol. ii. 1862, p. 207.

Vein and the North or Red Vein. The Old Vein has been formed in a fissure presenting all the characteristics of a fault, with a downthrow to the N.E. Its course is nearly S.E. and N.W., with a dip of about 80° from the horizon towards the N.E.; this vein at times swells out into large masses of ore and gangue, the latter chiefly consisting of calcite and pulverulent quartz; it then again decreases in size and becomes nipped or otherwise impoverished. In some places it attains a thickness of fifteen yards, while five yards is by no means an uncommon width; and in such cases two nearly parallel levels were sometimes driven at the same horizon in the vicinity of its walls.

Towards the west the veins undergo a change, becoming, themselves, less productive, but apparently acting as feeders to various irregular pipes and floors of lead ore. Under these conditions some exceedingly rich deposits of ore have been met with, and the enormous cavern-like excavations found in various parts of the older workings sufficiently attest the truth of statements which have been handed down respecting the large amounts of ore which were obtained from them. In this part of the mine the country rock is a compact white limestone, and the ore deposits are unaccompanied by veinstone of any kind. The vein fissures are often very open, and show evidence of the action of carbonic acid upon the limestone. These openings form channels for the passage of immense quantities of water, carrying with it, in rainy seasons, a considerable amount of clay and sand.

Near the eastern extremity of the workings, this vein, in the upper levels, occurs in slates and shales belonging to the Coal-measures and Millstone Grit, and is usually very poor. At a greater depth it intersects the Carboniferous Limestone and becomes to some extent productive for lead ore, but instead of being filled with galena, the vein is, to a large extent, made up of brown blende, which is frequently well crystallized. This ore is mixed with pulverulent and massive quartz, and contains disseminated masses of galena.

The North Vein, like the Old Vein, to which it is nearly parallel, has been formed on a line of fault, and has a down-throw to the N.E., but apparently to not quite so great an extent; its throw however increases towards the east. The deposits of ore in this vein have often been exceedingly pure and massive, frequently containing not more than 15 per cent. of impurity as drawn from the mine. The character of the ore and its associated minerals differs in some respects from those of the Old Vein in the same ground.

The ore is steely and fine-grained, with very little admixture of large-grained cubical galena, but although fine-grained it seldom contains above four ounces of silver per ton. Blende is almost the only associated mineral. The walls of this vein are very imperfectly defined and sometimes can scarcely be said to exist.

In 1864 the Minera Mines produced lead ore and blende of the value of £103,293; of late years, however, the yield of lead ore has considerably fallen off, although a larger amount of blende has been annually raised. In 1881 these mines produced 1,394 tons of lead ore, 5,468 tons of blende, and 6,970 oz. of silver. Their present greatest depth is 158 fathoms.

In 1881 the production of lead ore in Flintshire was 4,392 tons, equivalent to 3,297 tons of metallic lead, and 29,000 oz. of silver.

During the same year the mines of Denbighshire yielded 1,587 tons of lead ore, or 1,193 tons of lead, and 7,055 oz. of silver.

ANGLESEA.—Parys Mountain is situated about two miles inland from the northern coast of the Island of Anglesea, its barrenness contrasting conspicuously with the fertile pasture lands of the surrounding country. Its height above the sea does not exceed 500 feet, but although the larger portion of its surface is covered with sufficient soil to support ordinary vegetation, it nevertheless scarcely produces either a blade of grass or a bunch of heather. This mountain, which was at one time widely celebrated for the very large amount of copper annually obtained from its southern slope, was in modern times first systematically explored in the year 1768. Since that period, like all similar enterprises, its mines have been subject to numerous fluctuations, but they have, notwithstanding, remained constantly in operation. They lie somewhat less than two miles south of the town of Amlwch, and are enclosed in a band of Silurian slate, which stretches in a southwesterly direction almost across the island. At Parys Mountain these slates are intercalated with bands of felspathic rocks of presumably eruptive origin, but which do not appear to have ever been carefully examined. The sketch section, Fig. 54, will serve to explain the order of sequence of the various rocks.[1]

The northern slope of the mountain consists of slate, *a*, in which occur small irregular branches of quartzose and felspathic rock, together with occasional bands of a greenish trap. This is followed by a very powerful quartz vein, *b*, which traverses the hill from one

[1] T. F. Evans, "The Mines of the Parys Mountain," *Trans. Manchester Geol. Soc.*, vol. xiv. 1878, p. 357.

side to the other, and is known as the Carreg-y-doll Lode. To this succeeds a thick band of felstone, *c*, which varies considerably both in colour and in texture. A band of deep blue slate, *a'*, follows this on the south, and is itself succeeded by another band of felspathic rock, *c'*, very similar to the last, beneath which is the slate, *a''*. As shown in horizontal section, Fig. 55, the rock-mass is traversed nearly

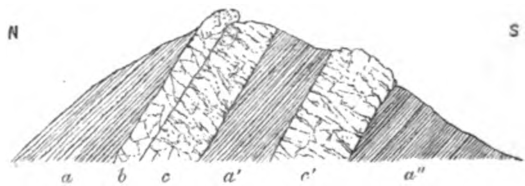

FIG. 54.—Parys Mountain; transverse section.

at right angles to the strata by two distinct faults, known respectively as the Great Cross-course and the Carreg-y-doll Cross-course. The former is of considerable width, varying from 20 to 60 feet, filled with broken and crushed fragments of the neighbouring rocks, and interfering considerably with the continuity of the strata. The

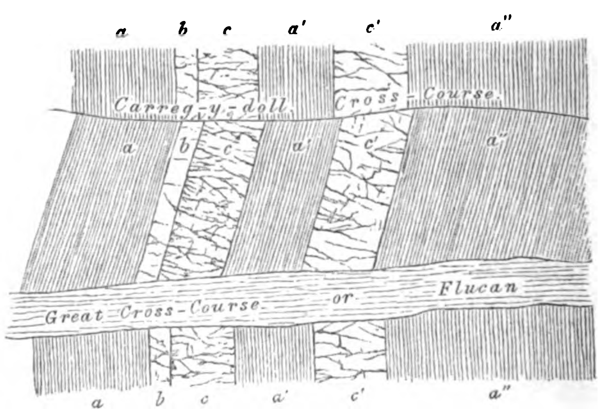

FIG. 55.—Parys Mountain; horizontal section.

latter, on the contrary, is a mere transverse cleft which has but little effect on the relative positions of the rocks forming its sides.

The central dislocated block of the felspathic rock, *c*, lying between the two cross-courses exhibits evidences of decomposition and disintegration which are not met with in other portions of its course, and it, in many places, consists of a soft concretionary mass containing so many shell-like nodules, that the miners have given it the name of *Carreg-y-Grogan*, or shell-stone. In these, kernels of copper pyrites occur in such large quantities that this ground has formed one of the most profitable resources of the mines.

In addition to the foregoing, and beginning at the north in the band *a*, a large deposit of copper pyrites associated with quartz, &c., known as the North Discovery Lode, extended from a few fathoms west of the Great Cross-course for a distance of 90 fathoms westward. This more nearly resembled an ordinary lode than any other which has been discovered in the mines. It was well defined and was enclosed in a country rock of hard slate, dipped at an angle of 60°, and the shoot of ore which it carried inclined westward at the rate of three feet in a fathom. It was also distinguished from all other similar deposits by the almost complete absence of felspathic rocks. This great deposit has now been completely worked away, after having yielded, in the aggregate, copper ores of the value of about a million pounds sterling.

With the exception of some small quartzose strings, sometimes containing a little copper pyrites with blende and galena of no commercial value, no ore occurs between this and the Carreg-y-doll Lode. This is an immense sheet of quartz, *b*, varying from five to sixty feet in thickness, and sometimes containing valuable bunches of copper pyrites; iron pyrites is also present, but not in such large quantities as in the rocks lying to the south. This lode contains druses or vughs of extraordinary dimensions, one of them, cut into some years ago, which was beautifully lined with crystals, being no less than eight fathoms in length and four in height. The bunches of ore in this lode, like those before described, exhibit a tendency to dip towards the west.

The large felspathic band *c* also encloses considerable deposits of copper pyrites, which occur in the form of strings and bunches. This ground has yielded large profits, and a considerable amount of copper is still disseminated through the rock, but it is too sparsely scattered to repay the expense of mining and concentration.

Extensive as these deposits may be, they are much less important than are those which occur to the south of the felspathic band, and which lie immediately between it and the band of slate marked *a'*. At the junction of these two rocks the mountain has been almost divided into two parts by two large open-cast excavations varying in depth from 110 to 140 feet, and occupying an area of somewhat more than twelve acres in extent. These are bounded on the north by the band of felspathic rock marked *c*, and on the south by the stratum of slate *a'*. It is here that occurred the great body of copper ore which once exercised a considerable influence upon the European copper market. The ores did not, on an average, contain more than 5 to 6 per cent. of copper, but for a time there was scarcely any limit to their possible production, and the proprietors, to a large extent, commanded the market.

The metalliferous mass worked in these open cuttings is composed of three distinct members, namely :—

1st. A bed of iron pyrites.

2nd. A bed of copper pyrites.

3rd. A thick bed of an ore locally known as *bluestone* sometimes lies beneath the deposit of copper pyrites.

This ore varies somewhat in composition, but the following analysis, made by Mr. F. Claudet, may be taken as approximately representing its average composition.

Lead	14·46
Copper	2·13
Zinc	27·89
Iron	11·45
Sulphur	29·05
Siliceous rock	14·47
	99·45

Silver	6 oz. 15 dwt. per ton.
Gold	traces.

The iron pyrites and chalcopyrite invariably occur associated with quartz and felspathic rock, but the bluestone is usually nearly pure, containing only branches and nodules of white quartz. The stratum of this mineral, which underlies the other two beds of ore, is by no means regular, having sometimes a thickness of from 50 to 60 feet, while at others it is reduced to a few inches or entirely disappears. It occurs in its purest state when intermixed, in the form of elongated lenticular masses, with the enclosing slate. Large quantities of this ore might be raised if a satisfactory market could be obtained, but, although much attention has been bestowed on its metallurgical treatment, none of the processes hitherto tried appear to possess the necessary simplicity, and the demand is consequently somewhat limited. The beds of pyrites and bluestone appear to thin out in descending, while that of copper ore would seem rather to improve in depth.

The water from these mines contains a considerable amount of the sulphates of iron and copper. This water is first raised to the surface by wooden pumps, and then stored in reservoirs prepared for its reception. In these it deposits all the sand and clay it may hold in suspension, and when it has become perfectly clear it is tapped off into the precipitators as may be required. Into these scrap iron is introduced and the copper thrown down in the usual way. After the precipitation of the copper, the water, which has been treated by metallic iron, is allowed to flow into large basins several acres in extent, where, by a natural process of oxidation, it deposits highly basic salts of iron, which are largely used for the purification of coal gas and for the manufacture of various iron-oxide paints. Of this *ochre* the Anglesea mines sold, in 1881, 3,011 tons; with 2,305 tons of bluestone, and 768 tons of copper in the form of ores and precipitate.

ISLE OF MAN.

Underlying the Silurian and Carboniferous rocks, which are well represented in the Isle of Man, and breaking through them in various places, are granite and other igneous rocks. The granite is found at the surface in two localities, one in the north of the island between Laxey and Ramsey, and the other in the centre on the eastern side of South Barrule. In addition to these granitic outbursts, dykes of porphyry and diabase exhibit traces of volcanic action in all parts of the island. Everywhere the adjacent strata are greatly altered by contact with the granite or other igneous rock, and metalliferous minerals occur abundantly near the line of contact.

The two principal mines, Foxdale and Laxey, are situated near the great outbursts of granite; Laxey being near the northern and Foxdale near the southern mass. Resting on the granite is a series of slaty rocks, which occupy more than two-thirds of the entire area of the island. Valuable metalliferous veins traverse these slates, and for many years mines have been worked with great success both at Foxdale and Laxey, and, less profitably, in several other parts of the island.

At Laxey the direction of the main lodes is about 8° E. of N., with an easterly underlie of two feet in a fathom. At Foxdale the principal lodes course 8° S. of E., with a southerly underlie also of two feet per fathom. The main lode has been worked, but not quite continuously, for about four miles on its east and west course, and in this distance is intersected by several counter veins, and by at least three north and south veins, all of which have a dip towards the west. The Laxey Mines are worked exclusively in Lower Silurian slate, but in the Foxdale Mines the deeper workings are entirely in granite, which was reached after first passing through the slate into a layer of granite thirty feet in thickness, and then again sinking through a band of slate. A new perpendicular shaft is now being sunk, which is intended to intersect the lode at a depth of 250 fathoms.

Foxdale is remarkable for the great size of its main lode, which occasionally expands to a width of forty feet. To the mineralogist Foxdale is extremely interesting. In the large cavities or *lochs* in the lode, magnificent crystals of iridescent galena are often found. The galena has occasionally a very high percentage of silver. Argentiferous tetrahedrite is frequently to be met with, as also are splendid pseudomorphs of iron carbonate after fluor spar, resembling those formerly found at the Virtuous Lady Mine near Tavistock. Recently plumosite, the *Federerz* of the Harz miners, has been discovered.

Of late years, a remarkable feature has been the presence of large quantities of carbonic acid gas, given off from crevices in the south wall of the lode. At the present time (1883) in the eastern end of the 185-fathom level, the amount of gas is so large that, although volumes of compressed air are continually being poured in from two air-pipes, the men experience the greatest difficulty in working; and, as candles will not burn, the value of the end can only be determined by the ore brought out. The yield of the Foxdale mines during the year 1881 was 3,419 tons of lead ore containing 69,080 oz. of silver.

At the present time, the deepest portion of the Laxey Mines is 259 fathoms below the adit. In 1881 they yielded 1,700 tons of lead ore containing 5,250 oz. of silver, and 7,567 tons of blende. The other mines in the Isle of Man returning lead ore were Ballacorkish, where fine specimens of the carbonates and phosphates of lead occur, East Foxdale, Kirk Michael, and North Laxey.

Evidences of mining operations for copper carried on at a very early date, have been observed at Bradda Head. This lode, at the S.W. corner of the island, is one of the finest surface exhibitions of a mineral vein to be seen in Europe.[1]

Several attempts have been made, with more or less success, to

[1] W. W. Smyth, "Metallic Mining," *Stanford's British Manufacturing Industries*, vol. i. 1876, p. 15.

work the hæmatite lodes which are found at Maughold Head, near Ramsey.

According to the statistics of the Mining Record Office, the total returns in 1881 from mines in the Isle of Man amounted to 5,675 tons of argentiferous lead ore of the value of £76,513, and 7,567 tons of blende worth £28,701; with 120 tons of hæmatite worth £60, and 60 tons of copper ore worth £90; making the total value of metalliferous minerals produced in the island £105,364.

IRELAND.

Mines are by no means numerous in Ireland, for, although ores of various metals are not of unfrequent occurrence, there would appear to be but few localities in which they occur in sufficient abundance to render their extraction remunerative.

WICKLOW.—The county of Wicklow is composed of slaty rocks chiefly of Lower Silurian age, which are broken through by masses of granite and intersected by dykes of porphyry and greenstone. In the neighbourhood of the granite the clay slates are often converted into mica schists, granulite, or quartzite, and the metalliferous deposits of the district are, for the most part, comprehended within a somewhat narrow belt extending for some distance on either side of the junction of the granite and schists. They may be divided into three principal groups, namely:—

1.—Deposits of copper ores and of cupriferous iron pyrites chiefly in Silurian slates.

2.—Lead ores in granite.

3.—Gold in the sands and gravels of various streams near the base of Croghan-Kinshella.

There are several copper mines in the county of Wicklow, some of which are said to have been wrought from very ancient times. Up to the year 1839 those of the Ovoca district were worked exclusively for copper, excepting that a certain amount of lead ore was raised at Cronebane and Connary. About the time above referred to a sudden demand for pyrites sprang up in this country, in consequence of the suspension of the sulphur trade with Sicily, and for many years these mines were worked principally for iron pyrites. At the present time Irish pyrites has been almost entirely superseded in the manufacture of sulphuric acid by that imported from Spain and Portugal, in consequence of which the mines of Wicklow, although once yielding 60,000 tons of pyrites annually, are now no longer actively worked. It was formerly supposed that the ores occurred in deposits having the same strike and dip as the enclosing rocks, but more recent investigations have conclusively shown that, although in their general direction they approximate more or less closely with the general strike of the country, they nevertheless invariably cross the strata, although often at a very small angle. In depth the lodes always underlie faster than the enclosing rocks.[1]

The country consists principally of slates and schists, all of which are more or less metamorphosed, and associated with them are various pyroxenic and felspathic rocks. The former are generally regarded as being of eruptive origin, but the felspathic rocks exhibit somewhat remarkable peculiarities. At one time they were supposed to run parallel with the channel of mineral ground enclosing the lodes, but it has been pointed out by Mr. W. W. Smyth that in some places they run across it; and Mr. Kinahan has shown that they sometimes occur in isolated masses, and that, although some of them are intrusive rocks, the majority may be regarded as being of metamorphic origin.

The lodes upon which mining operations have been conducted east of the Ovoca River are principally in clay slate, and occupy a belt extending from the Ovoca for about six miles in a northeasterly direction. The principal lodes are not, however, continuous throughout this distance, but are much interrupted by faults, and sometimes become either greatly reduced in width, or appear to die out altogether; patches of dead ground sometimes intervene, in which no regular veins have been discovered.

In West Cronebane there is, on an average, a depth of six fathoms of drift over the back of the lode, and under this there is a breccia composed of angular fragments of country rock cemented together by hydrated oxide of iron. This latter rests upon the gossan, which here consists of limonite, nearly the whole of which was removed some years since, at a time when iron ores were in exceptionally great demand. In a westerly direction the breccia and gossan gradually thin out, until upon Tigroney brow both have been removed by denudation, and the unaltered pyrites makes its appearance on the surface. In West Cronebane the gossan in some places rests upon a ferruginous clay, and at one point carbon is present in the form of a graphitic shale. Occasionally the gossan is found to rest on clay containing patches and strings of melaconite

[1] P. H. Argall, "Notes on the Ancient and Recent Mining Operations in the East Ovoca District," *Proc. Roy. Dublin Soc.* vol. ii. 1880, p. 211.

and fahlerz, with occasional veins of pyrites composed of detached sand-like crystals, which in depth become consolidated and lose their granular character. In proportion as the thin branches of pyrites proceed downwards they increase both in width and number, thus gradually replacing the laminæ of the enclosing killas until, eventually, the entire width of the lode is composed of pyrites. Still further down the iron pyrites becomes more dense, but is frequently interlaminated with bands of hard killas, and under these circumstances the hardest ribs not unfrequently contain two per cent. of copper.

At Tigroney and West Cronebane the country rock, for a considerable distance both north and south of the great pyrites vein, is mineralized by finely disseminated particles of iron and copper pyrites, and these minerals having become oxidized near the surface impart a reddish-brown colour to the partially decomposed rocks. In these mineralized rocks, for a distance of 25 fathoms south of the main lode, are lenticular deposits of yellow copper ore. As first pointed out by Mr. Weaver, these rocks are traversed by horizontal joints, of which the extent is unknown, but which are sometimes two inches in width, while at others it would be difficult to insert the blade of a knife. These joints usually occur at intervals in depth of about five fathoms, and are crossed nearly at right angles by a system of almost perpendicular joints, by which the country is divided into huge nearly rectangular masses. None of the copper deposits are accompanied by any gossan; but when one of these joints comes into the immediate vicinity of a deposit of copper ore, it becomes partially filled with small fragments of country rock, cemented into a breccia by hydrated ferric oxide and stained by various compounds of copper.

These deposits of yellow copper ore are generally lenticular masses intercalated between the laminæ of the strata, gradually thinning off to nothing both in length and depth. In some cases two or more of such deposits are connected together by branches or strings. Associated with these deposits are counter lodes, many of which occupy the perpendicular joints before referred to; and when these come in contact with lenticular deposits they form junctions with them, and they themselves for a certain distance contain copper ores of above the average produce. Lenticular masses of cupriferous pyrites are sometimes intercalated with the ordinary iron pyrites of the great lode.

The mode of occurrence of the iron pyrites and chalcopyrite at Tigroney and West Cronebane will be understood by referring to

Fig. 56, in which *a* represents the main lode, displaced by various faults, and *b* lenticular deposits of yellow copper ore on its south wall. Fig. 57 is a transverse section on the line *d e*, in which the lenticules of yellow copper ore shown south of the lode are not indicated by a letter. At the surface the lode was at this point eight fathoms in width, decreasing to six fathoms at the 77-fathom level, below which it was suddenly cut off by a slide underlying 45°

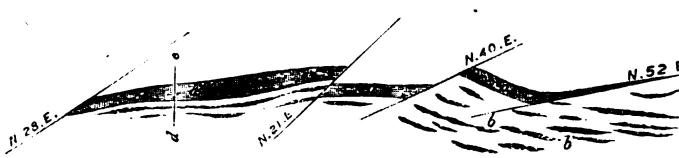

FIG. 56.—Tigroney and West Cronebane; horizontal section.

south. This slide was sunk upon for a distance of thirteen fathoms, where a vein of cupriferous pyrites was found two feet in width, the walls of which were opening out in depth. The vein has not been proved below the 90-fathom level, which is the deepest point reached in any of the eastern Ovoca mines. The great sulphur lode in West Cronebane is cut off towards the east by dead

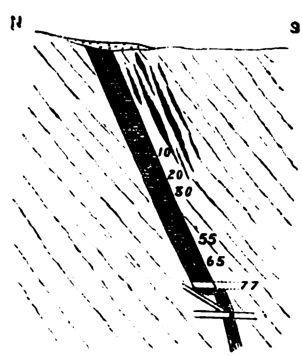

FIG. 57.—Tigroney; transverse section on *d e*.

ground, and is not again met with in a workable form until East Cronebane is reached, a distance of 300 fathoms. This lode in East Cronebane and Connary is wedge-shaped, and becomes gradually smaller as the depth increases. At one or two points it has been followed down almost to the point of a wedge, but it is not impossible that further exploration might lead to the discovery of a splice, and that the lode may thus continue in depth.

South of the Connary main lode is Wall's Lode, with a similar bearing and underlie, which for a short distance yields iron pyrites with a little chalcopyrite. Towards the east it breaks up into a number of strings, while westward it is cut off by a mass of felspathic rock. Further north-east is another deposit of metallic sulphides known as the Kilmacoo Lode, which is chiefly made up of clay and soft ground, containing bunches and veins of a bluestone having nearly the same composition as that found at Parys Mountain in Anglesea. This bluestone, which is sometimes called *kilmacooite*, yields from six to eight ounces of silver per ton of ore, together with traces of gold. The copper ores from the Wicklow mines contain from 8 to 12 per cent. of copper, while the iron pyrites affords from 33 to 36 per cent. of sulphur. About one-sixth of the iron pyrites is to some extent cupriferous, containing from 1 to 2 per cent. of copper, and about 38 per cent. of sulphur. Nearly all the pyrites from these mines contain minute quantities of gold, silver, nickel, and cobalt. A certain amount of copper is annually obtained from the mine waters by precipitation with metallic iron. At the present time the total annual yield of copper from the Wicklow mines, including that obtained in the form of precipitate, does not amount to 100 tons.

The most productive lead veins of the county of Wicklow have been those worked in the mines at Glendalough and Luganure, of which the last only is at present in operation. The veins of this district have never presented any features of especial interest, excepting that courses of nearly pure galena 3 feet in width have occasionally been found in them; the veinstone is principally quartz. The yield of Luganure in 1881 amounted to only 822 tons of lead ore, containing 616 tons of lead and 4,932 oz. of silver. The only other Irish lead vein from which Mr. Hunt's statistics give any returns for that year is Newtownards, County Down, which yielded 27 tons of lead ore, equal to 20 tons 10 cwts. lead, representing a value of £254. The Government Geological Survey has shown that the copper and lead veins of Wexford, and probably those of Wicklow also, are older than the tin-bearing lodes of Cornwall.

Gold was doubtless obtained by the ancient Irish by washing the sands and gravels of certain streams and rivers. Gerard Boate, in his "Natural History of Ireland," published in 1726, mentions the occurrence of gold in Londonderry, since which time none appears to have been found there. Mr. Kinahan states that pieces of gold have in late years been picked up in the valley of the Dodder, and that quite recently a small nugget was found on St. Stephen's Green, Dublin, in a load of gravel which had been brought from the Dodder Valley.[1] In modern times gold was not generally known to exist in Wicklow until about ninety years ago, when it was remarked that persons from that part of the country occasionally brought small pieces into Dublin for sale. Not much attention appears to have been directed to the subject, until the finding of a nugget weighing 21½ oz. awakened public curiosity and caused inquiries to be made, the result of which was the discovery that it had been found in a rivulet flowing eastward, over Lower Silurian rocks, from the high granitic mountain of Croghan-Kinshella, on the borders of Wexford, and joining the Aughrim, a tributary of the Ovoca, at Woodenbridge. This discovery caused a great rush to take place in 1795, and a considerable amount of gold was collected by the diggers during the first six weeks, at the end of which time the Gold-mine Valley was taken possession of by the Government, while the operations of the country people were confined to the neighbouring streams of Knockmiller and Clonwilliam, Ballintemple, and Coolballintaggart, of which the last runs northward from Croghan-Kinshella. In addition to the washings along the beds of these streams, shallow placer workings were opened further north at Mucklagh, Ballinagappoge, and Ballycreen, on tributaries of the Aughrim or Ow River.

The Government works, under the superintendence of Messrs. Mills, King, and Weaver, were actively carried on until May 1798, when they were interrupted by the Irish Rebellion, and not again resumed until the spring of 1801, when, in addition to the usual placer mines, a level or tunnel was driven into the eastern face of Croghan-Kinshella, and several miles of trenches were sunk to the bed-rock in various directions. In these workings numerous irregular branches of quartz were cut through, but in no instance was a particle of gold found *in situ*; and the alluvial gold having become practically exhausted the works were eventually abandoned.

The placer mining of the Government is said to have been remunerative, but the whole of the money thus realized was subsequently expended in trying to find gold in its natural matrix. The total amount obtained was 944 oz. which, when melted and run into bars, assayed on an average 21½ carats fine, and was at the price of the period worth £3,675. The alloy consisted of silver with a little copper. Sir R. Kane states that the gold collected by

[1] G. H. Kinahan, "Geology of Ireland," London, 1878, p. 340.

private individuals sold for above £10,000. Since the period referred to, placer mining has at various times been resumed, but never with any marked degree of success.

Different observers have remarked that the auriferous gravels of Wicklow are invariably found at a lower level than the outcrops of certain neighbouring veins containing ores of iron and copper, through the disintegration of which the gold is supposed to have been liberated. But although gold is elsewhere often found in quartz containing various metallic sulphides, none has ever been discovered in the undecomposed portions of the mineral veins of Wicklow. Its presence has however been detected a little to the north-east in the gossans of the Ballymurtagh, Cronebane, and Connary Mines, to the west and east of the valley of the Ovoca. Some of the nuggets found have had, however, attached to them fragments of quartz, and it is consequently evident that a certain amount of auriferous quartz must exist somewhere in the neighbourhood.

According to Mr. Weaver the following minerals accompanied gold in the drifts and gravels of the Wicklow placers, namely, ilmenite, specular iron ore, red and brown hæmatite, iron pyrites, oxide of manganese, garnets, quartz, and chlorite. To these Mr. Mallet has added the following: platinum, cassiterite, wolfram, magnetite, molybdenite, galena, chalcopyrite, topaz, zircon, corundum, &c.[1]

Tinstone occurred more frequently at Ballinasilloge than in the higher ground near Ballinavally. The pieces of gold were, for the most part, much water-worn, but angular fragments were exceptionally met with. None of the gold diggings of Wicklow have been worked otherwise than as shallow placers, but since gold has been found in so many of the smaller tributary streams, it might be anticipated that, like in other gold-producing countries, it would be found in the deeper detritus on the banks of the larger rivers. These do not appear to have ever been explored, but Mr. Kinahan has suggested that gold may perhaps exist in paying quantities beneath the river and estuarine gravels at Woodenbridge and various other points in the valley of Ovoca. A few specks of gold have occasionally been found not only in the gossans at Ballymurtagh, Cronebane, &c., as already stated, but also in those of the copper lode at Carrigat or Dhurode, south of Bantry Bay, in the county of Cork.

IRON ORES OF MIOCENE AGE.—Iron-ore measures belonging to this age represent an important feature of the Miocene rocks of

[1] William Mallet, "On the Minerals of the Auriferous Districts of Wicklow," *Phil. Mag.*, vol. xxxvii. 1850, p. 392. The presence of platinum was by no means satisfactorily determined by Mr. Mallet.

Ireland; and, although usually classed as one series, they are believed to occur on slightly different geological horizons. They comprise beds of pisolitic iron ore, aluminous iron ore, bole, and lithomarge, often associated with lignite. At some of the iron mines the thickness of these measures exceeds 60 feet, while in others it scarcely amounts to so many inches.[1] The Tertiary rocks of Antrim comprehend dolerites, basalts, and tuffs, the latter including the iron-ore measures, &c. The dolerite rocks may be divided into two series, the upper and the lower; the first of these being above the principal iron-ore measures, while the second is below them. The dolerites and basalts occur in the form of flows, protrusions, and dykes, while associated with them are bole and laterite with beds of ferruginous lithomarge and aluminous and pisolitic iron ore, in which last are occasionally beds of lignite.[2]

The dolerites are often somewhat coarsely crystalline and occasionally even porphyritic, and they not unfrequently exhibit a columnar structure; very large areas are covered by doleritic and basaltic rocks, but the tuffs are of more limited extent. The thickness of the flows of dolerite varies from a few feet up to 40 feet, while between them are accumulations of bole, a material closely resembling the laterite which, in India, covers to a great depth vast areas and contains deposits of nodular iron ore. In Ireland the thickness of these beds or partings seldom exceeds 70 feet. In some places the ferruginous accumulations graduate into aluminous iron ore of good quality, but in such cases they are not generally pisolitic, although the aluminous ores occasionally assume this structure if they come immediately in contact with a deposit of pisolitic ore. The beds of laterite between the flows of dolerite are usually of a reddish-brown colour, and are very tough. They have an amygdaloidal structure, and contain cavities enclosing aragonite with various zeolites.

The partings between the lower beds of dolerite are generally softer than those dividing the upper series, and frequently graduate into either ochre or bole. This does not take place so frequently between the upper dolerites, but in all cases, the iron ore alone excepted, the material constituting the dividing beds is throughout vesicular.

The iron-ore measures of Antrim vary in thickness from 10 to 70 feet; in the Glengariff Mines they do not, according to Mr. Argall,

[1] G. H. Kinahan, "Geology of Ireland," p. 164.

[2] Philip Argall, "Notes on the Tertiary Iron Ore Measures, Glengariff Valley, County Antrim," *Proc. Roy. Dublin Soc.*, vol. iii. 1881, p. 151.

exceed 60 feet, and, with the associated rocks, afford the following section:—

		Feet.
TERTIARY	Upper dolerites	300
	Iron-ore measures	60
	Lower dolerites	250
	Basal conglomerate	2
CRETACEOUS . . .	White limestone	70
	Total	682

The iron-ore measures are composed as follows:—

			Ft.	in.
6. Steatitic rock;	local name	Brushing	0	8
5. Steatitic clay	,,	Holing . . 1 in. to	0	3
4. Pisolitic ore	,,	First ore	1	7
3. Aluminous ore	,,	Second ore	2	6
2. Ochreous rock	,,	Pavement	15	0
1. Lithomarge	,,	Marge	40	0
		Total	60	0

The lithomarge usually rests upon an irregular flooring of dolerite, which is in places corroded into deep holes. Boulders and masses of dolerite, externally much decomposed, are also found embedded in the bottom beds of the lithomarge and often pass insensibly into this rock. The lower beds of lithomarge are usually of a light lavender tint, and contain numerous small spots of beauxite; while the upper layers are brown or nearly black. It is a brittle, splintery rock, which flies before the pick, but is nevertheless readily cut with a knife. In the immediate vicinity of an eruptive dyke it becomes a very tough rock, and on exposure to the atmosphere it rapidly exfoliates. Interstratified with lithomarge are deposits of aluminous iron ore, usually in the form of beds varying in thickness from a few inches to several feet; but they sometimes also occur as lenticular intercalations. Small partings and seams of a siliceous lignite are sometimes found in the aluminous ore as well as in the pisolitic variety, but seldom or never occur in the lithomarge. It has been observed that when peat water flows over an exposed surface of lithomarge a deposit of oxide of manganese frequently takes place in its cavities and interstices.

The ochreous rock above the lithomarge is called the "pavement," and forms the floor of the iron-ore measures. It seldom contains beauxite, excepting in the immediate vicinity of a dyke, where considerable masses of that substance frequently occur.

On the pavement rests the aluminous or second iron ore, the upper portions of which are to some extent pisolitic, and on this lies the first or pisolitic ore. The pisolitic ore varies considerably in thickness, but sometimes reaches 30 inches. In colour it is either brown or black, some of the pisolites of the latter colour having the appearance of graphite. These are more or less magnetic, many of them consisting chiefly of magnetite. The pisolitic iron ore usually contains from 30 to 70 per cent. of iron oxide, from 2 to 10 per cent. of alumina, from 5 to 10 per cent. of silica, and from 9 to 11 per cent. of titanic oxide. Sulphur is entirely absent, and only minute traces of phosphorus are occasionally present. The aluminous ores contain from 25 to 35 per cent. of iron, from 34 to 37 per cent. of alumina, and from 12 to 16 per cent. of silica. They are free from sulphur, only occasionally contain traces of phosphorus, and titanic oxide is entirely absent. These ores are largely employed as a mixture in smelting hæmatites.

Lignite and beauxite occur in the iron-ore measures of County Antrim, and usually replace the pisolitic seam, although in some places the lignite is separated from the ore by a band of beauxite. Intervening between the pisolitic ore seam and the roof are two beds of steatitic clays, known respectively as "holing" and "brushing." These clays contain numerous pisolites of aragonite, and similar nodules of that mineral are by no means uncommon in the lower bands of dolerite. The iron measures of Antrim are often penetrated and displaced by basaltic dykes, whose general bearing is a little east of north, and which vary in thickness from a few inches to several fathoms. They have frequently a columnar structure, the bases of the columns being nearly at right angles to the walls of the dykes.

These iron-ore measures are supposed to be of lacustrine origin, and to have been formed in shallow expanses of water in basins resulting from successive but unequal flows of dolerite. Lignite occurs in this rock near Crumlin, east of Lough Neagh; Carnmoney, south-west of Carrickfergus; Ballypalady, east of Antrim; also in the face of the cliff near the Giant's Causeway; and at Dunagael, Rathlin Island. Generally speaking, lignite is more or less associated with the ironstone measures, but in some cases it occurs between beds of dolerite. At Lemeneigh, west of Ballintoy, the lignites contain blocks of wood which split with great facility, while, still further west, the wood is but slightly mineralized and remains very much in its original condition. In the clay below the lignite are found plant remains, one of which is considered by Bailey to be *M'Clintockia Lyellii*, a plant previously found only in Greenland.

The principal localities at which pisolitic iron ores have been worked are along the outcrop of the beds from Knockboy and Ballylig, near Broughshane, to Glenravel, Cargan, and Newtown Crommelin; on the sides and at the head of Glengariff; near Carnlough and Glenarm; at Shane Hill, west of Larne; on Island Magee; at Ballypalady; near the Giant's Causeway; and a little inland from the White Rocks near Portrush. The whole of the workings are in the country lying north and north-east of Lough Neagh.

During the year 1881 there were exported from County Antrim 198,429 tons of this ore, the only other iron ores produced in Ireland being gossans from Ballymurtagh, County Wicklow, amounting to 1,433 tons.

OTHER MINING LOCALITIES.—That workings for copper ore were carried on at a very early period in the Bonmahon district, County Waterford, is rendered evident by a number of ancient wooden mining tools, which were discovered by Mr. Petherick in some old workings on the Stage Lode at Knockmahon. During the course of the last century the Knockmahon Mines were worked at different intervals and with somewhat varying success; in the aggregate, however, they have produced large quantities of copper ore and have sometimes yielded considerable profits to the adventurers. The lodes, which traverse Silurian rocks and are intersected by numerous cross-courses, are, according to Kinahan, of Pre-Carboniferous age, and are cut off by certain red conglomerates and sandstones, probably of Old Red Sandstone age. The general direction of the lodes is west of north, and the ground is traversed by various dykes of quartz-porphyry. The lodes at Knockmahon have, however, been worked down into very poor ground, and operations were ultimately suspended in the year 1880.

Some rich lodes, unknown to the ancients, were discovered about the year 1810 at Allihies, west of Bearhaven; and, under the name of the Bearhaven Mines, have since been successfully worked and have yielded large quantities of copper ore. The mines have now attained a depth of above 250 fathoms, but the returns have of late considerably fallen off. The lodes occur at the junction of the Yellow and Old Red Sandstone of the Cork type, and at the present time the annual production of the Bearhaven Mines is not above 832 tons of copper ore of 8¾ produce and of the aggregate value of about £4,500. The slaty regions, extending from Cork to the Mizen Head and beyond that point northward, enclose small veins containing copper ores of high percentage, such as erubescite and tetrahedrite; but, with the exception of Bearhaven, no great degree of success has hitherto attended mining operations in this part of Ireland.

SCOTLAND.

Although the earliest documents relating to mining in Scotland do not go further back than the twelfth century, the testimony of Roman writers and the number and variety of the prehistoric gold ornaments which have from time to time been found in that country, render it probable that the early population had worked the native sources of supply at a period long anterior to the beginning of written history. The first historical notice of gold occurring in Scotland is a grant in 1153 by David I., to the abbey of Dunfermline of a tithe of all the gold from Fife and Fothrif; and, in 1424, the Scottish Parliament granted to the Crown all the gold mines in Scotland.[1]

A document from the Balcarres MSS., printed in the *Analecta Scotica*, first series, pp. 91-94, shows that between the years 1585-1590, lead ore, to the amount of 15,717 stone, had been shipped from Scotland for foreign use. In the year 1593, Thomas Foullis obtained a take of all the mines in the sheriffdom of Lanark; and in 1707 an act of parliament exonerated and discharged Charles, Earl of Hopetoun, from a rent of 1,000 marks payable by him to the Crown in terms of the original grant. Another act gave him the right to pass the bridge of Ramwell Craig and Dunneden with lead ore and supplies for the mine and miners free of toll. This privilege was shared with the Duke of Queensberry.

GOLD.—As far as is at present known, the gold fields of Sutherland are all comprised within a radius of about ten miles around Benuarie, the gold having, for the most part, been found along the valleys of the tributaries of the Ullie or Helmsdale River.[2]

The principal streams which have been worked are the Kildonan, where gold was first discovered, the Suisgill, and the Torrish; these streams constitute what are known as the Kildonan diggings. Gold has also been found in the Altenbraichich, the Cinpreas, and the Craggie, all flowing into the Ullie. On the south side of the dividing range, called the Crask, gold has been

[1] R. W. Cochran-Patrick, "Early Records Relating to Mining in Scotland," Edinburgh, 1878.

[2] W. Cameron, "On the Sutherlandshire Gold Fields," *Trans. Geol. Soc. o Glasgow*, vol. iv. 1874, p. 1.

found in the Smeorol, a burn which falls into Loch Brora at Gordon Bush, and hence called the Gordon diggings. Further west, on another tributary of the Brora, known as the Black Water, gold has been likewise found.

The prominent geological features of the country are rocks which are regarded as being mainly of Lower Silurian age, consisting of granites, gneiss, mica schist, and quartzite, which, in a few localities only, are traversed by veins of quartz. Along the coast is a belt of coarse-grained granite. Old Red Sandstone sometimes caps the Silurian rocks, and Oolitic shales are found near the sea above the valley of the Brora. In the streams in which gold has been most plentifully found gneissoid and schistose rocks prevail, while the higher ground is everywhere so thickly covered by a deep deposit of peat that it is only at points situated at considerable distances apart that any rocks are exposed on the surface. In the beds of the rivulets on the high ground of the Kildonan hills, schistose and flaggy rocks largely predominate, and in the interstices between their laminæ gold is sometimes found.

On either side of the Kildonan, high moorland hills trend towards a range of quartzite running parallel with the Ullie, and confine the stream and its littoral flats within very narrow limits. Tributaries occasionally flow into the main burn and often afford good sections both of the rocks and drifts; the latter usually yielding a little gold. In some places the Kildonan itself has cut its way through beds of rock outcropping at the surface, while in others high banks of sand and pebbles afford evidence of extensive alluvial deposits. These flats are occasionally flanked by deep terraces of gravel and drift, from the surface of which, mixed with angular fragments of granite, grains of gold may sometimes be obtained by panning.

Towards the lower portion of the stream the rocks assume a more granitic character, and are associated with gneiss, micaceous and chloritic schists, and quartzites, which are occasionally traversed by veins of quartz. In some parts of the course of this stream granitic masses assume the form of dykes, and gold appears to be most plentiful when the stream forms an acute angle with the strata crossing its bed. As a rule the miners preferred working either in the vicinity of masses of granite, or in the neighbourhood of a partially decomposed greenish schist. The earlier operations of the diggers were exclusively confined to the banks of the streams where the bed-rock was above the level of the water. The gold was found chiefly in the lower drift, but it has been also obtained from all the various strata even up to the roots of the heather. The drifts vary materially in character, having sometimes the appearance of a ferruginous conglomerate, while in others the auriferous material is a yellowish felspathic detritus. The small proportion of rounded quartz pebbles and boulders, or in some instances their entire absence, would be considered remarkable by a person accustomed to the placer diggings of California or Australia. In nearly all cases the material which remains when the process of washing draws towards completion, is found to contain, along with the gold, a considerable proportion of titaniferous iron ore and magnetite together with a few small garnets. As before stated, the auriferous detritus is generally almost entirely composed of somewhat water-worn fragments of the local rocks; but in a few instances pebbles from the Old Red Sandstone and nodules of red hæmatite have been found among it. Latterly the miners no longer confined their operations to the shingle immediately bordering the streams, but advanced for some distance into the flats forming their banks, although with but very moderate success.

The Suisgill is a burn of about the same size as the Kildonan, but is flanked by deeper deposits of drift and by more extensive flats than that stream. In this rivulet the gold is coarser than that found in the Kildonan, and it is here that a two-ounce nugget is said to have been found. The same rocks present themselves along the course of the Suisgill that are seen in the bed of the Kildonan, although the latter affords better sections. Nearly all the other streams exhibit similar peculiarities, and a description of them is consequently unnecessary. It is evident that gold in small quantities is generally distributed throughout this part of Scotland, but there appears to be considerable difference of opinion with regard to its derivation. Sir R. Murchison believed the gold-bearing drift to have been brought from the Silurian plateau towards the central and western portions of Sutherlandshire, while Mr. Campbell of Islay is inclined to the opinion that at least a portion of it may have come from even Scandinavia or Lapland; both, however, consider the vehicle of transport to have been ice. No gold has as yet been found in this district *in situ*, and consequently no definite proof exists of its local origin. The drift is, however, composed of fragments of purely local rocks, while quartz pebbles, usually so plentiful in deposits of this nature, are almost entirely wanting. Influenced by these and similar considerations Messrs. Joass and Cameron are disposed to ascribe a granitic origin to the gold of this area. It is, however, possible that it may have been derived from the quartz veins which are seen in the ravines through which the streams severally flow, or from others which are now hidden under a covering of bog or other material.

Whether the gold which occurs in these drifts could under ordinary circumstances afford remunerative occupation to any considerable number of men, is open to grave doubt. When, however, it is stated, that a tax of one pound per month was levied by the Duke of Sutherland upon each miner for the privilege of digging for gold upon his waste lands, and that the Government further demanded one-tenth part of the gold found as Royalty, it will be easily understood why gold washing in this district was an industry of short duration.

LEAD, SILVER, AND NICKEL.—There are lead mines in the south of Scotland at Wanlock Head, now called the Queensberry Mines, in Dumfriesshire, and at Leadhills in Lanarkshire, where the veins occur in Silurian rocks. At Cally, in Kirkcudbrightshire, copper ore has been discovered, and stibnite has been found in the county of Dumfries. In neither case have they been turned to any account, although a small quantity of lead ore is annually produced in the first-named county. The lead mines of Strontian, in Argyleshire, were once of some importance, and a lead mine in schist has been worked at Tyndrum, and another in the Isle of Islay. Pentlandite, a sulphide of iron and nickel, was, some years since, worked at Glen Essochossan, two miles from Inverary, as well as at Craignure, in the vicinity of Loch Fyne, eight miles distant from the same town. About 300 tons of ore averaging 14 per cent. of nickel are stated to have been sold from these mines. In a sample of the ore from the Craignure Mine Mr. F. Claudet found, in addition to the usual percentage of nickel, a considerable amount of tin oxide.

Writing towards the latter portion of the eighteenth century Jars[1] states with regard to Leadhills :—" Le filon principal produit jusqu'à la plus grande profondeur où on l'exploite, de 100 pieds au-dessous de la galerie d'écoulement, du très-beau spath, du minérai de plomb à larges facettes, irrégulieres et cubiques, de la

[1] " Up to the greatest depth to which it is worked, 100 feet below the adit, the principal vein produces very beautiful spar, lead ore with large irregular and cubical faces, green, black, and non-crystallized white ore ; the latter also in white and very friable crystals. This variety is very beautiful and extremely rich in lead. I have seen this vein worked for a very great distance with a width of at least four feet, massive ore ; and I am assured that it enlarged as the depth increased, as at its greatest depth it is seven feet. This vein is one of the richest in Europe—I have not yet seen anything which approaches to it in abundance."—*Voyages Métallurgiques*, vol. ii. p. 531, Paris, 1780.

mine verte, de la noire, & de la blanche non-crystallisée, & de cette derniere en crystaux blancs & très-friables; cette espece est très-belle & extrêmement riche en plomb. J'ai vu exploiter ce filon sur une très-grande étendue, au moins de 4 pieds de largeur en minérai massif, & l'on m'a assuré qu'il s'élargissoit en approfondissant, puisqu'à sa plus grande profondeur il en avoit 7. Ce filon est un des plus riches qu'il y ait en Europe, je n'ai encore rien vu qui approche de cette abondance."

John Mawe,[1] writing at the beginning of this century, says: "The veins are in general large and extremely rich. The Susanna vein is the admiration of travellers, being a great rake vein which in some places has continued for a considerable way fourteen feet wide of solid ore. It is now full three feet wide and an amazing quantity is before the miners. The mine is about 100 fathoms deep with a fire-engine not now employed, a sufficient quantity of water having lately been procured to work the water-engines so as to keep the bottom dry." The mines of Strontian, in north-western Scotland, afford an example of the occurrence of lead veins in granite.

In 1881 the Leadhills produced 1,804 tons of lead ore containing 5,412 oz. of silver, of the total value of £17,138.

During the year ending June 1883 the quantity of ore dressed was 2,891 tons; 2,115 tons of ore were smelted, producing with the fumes 1,693 tons of lead.

In 1881 the Queensberry Mines, late Wanlock Head, yielded 1,826 tons of lead ore containing 8,000 oz. of silver, worth £17,347. In addition to the above the East Black Craig Mine, in Kirkcudbrightshire, yielded 176 tons of lead ore, value £1,628. During the same period 232 tons of copper ore, value £468, were produced in Shetland, and 323 tons of blende, value £607, were raised at the East Black Craig and Queensberry mines.

BLACKBAND IRONSTONE.—In Scotland the coal-bearing strata lying above the Millstone Grit are known as the upper Coal-measures, while the seams of coal in the Carboniferous Limestone belong to the lower Coal-measures. These measures stretch across the country in a south-westerly direction from the German Ocean to the North Channel. In addition to coal both the upper and lower series contain valuable seams of blackband ironstone. This term is applied to ironstones of a dark brown or black colour containing a sufficient amount of carbonaceous matter to enable them to be burnt in heaps without the addition of extraneous fuel.

[1] *Mineralogy of Derbyshire, &c.*, London, 1802, p. 137.

When thus burnt the residues often yield from 50 to 70 per cent. of metallic iron. Blackband ironstone is found both in the upper and in the lower series.[1]

The Upper contains—

	Thickness.
The Palace Craig Blackband	12 inches.
,, Airdrie	16 ,,
,, Bellside	6 ,,
,, Kiltongue	about 6 ,,
,, Calderbank or Kennelburn	,, 10 ,,
,, Slatyband	from 12 inches to 3 feet.
,, Lower Slatyband	,, 12 ,, ,, 18 inches.

The Lower series contains—

The Possil Upper Blackband	12 inches.
,, Possil Lower	12 ,,
,, Banton	12 ,,

All these ironstones have been found in some part of Lanarkshire, the principal seams being the Airdrie Blackband and the Slatyband. The former, now nearly exhausted, has been found in workable quantity within an area of only about ten square miles, but its equivalent in the form of a thin seam of coal covers an area of from fifty to sixty square miles. The Slatyband extends over a considerable area, but is variable both in thickness and quality, sometimes gradually thinning out and disappearing. It is found in Lanarkshire, Ayrshire, and Fifeshire, though in the last-named locality it is not of good quality. In Linlithgowshire it is represented by the celebrated Boghead cannel coal.

Blackband was discovered in Lanarkshire by Mushet in 1801, and has for many years been very extensively worked, but at the present time the supply is rapidly falling off. The yield of blackband ironstones is at the rate of 2,000 tons calcined ore, equivalent to 1,000 tons pig iron, per acre for each foot in thickness.

Clay ironstone is worked in connection with the Shotts Furnace Coal and the Ball or Coalinshields Coal, and two bands of clay ironstone occur in the underlying Millstone Grit series, namely, the Ginstone and the Curdley or Curly ironstone. Clayband ironstone of good quality was formerly obtained at Banton and Denny in the Carboniferous Limestone series. Several seams of the same mineral have been mined at Falkirk among the strata immediately overlying the Slatyband ironstone. This ore has also been obtained from the horizon of the Brighton Main and the

[1] Ralph Moore, "On Coal and Ironstone Mining in Scotland," *Proc. S. Wales Inst. of Eng.* vol. iii. 1864, p. 239.

Auchingane coals. Of the 2,595,375 tons of ironstone produced in 1881 in Scotland, 1,402,700 tons were Blackband and 1,192,675 tons Clayband.

GENERAL SUMMARY OF THE PRODUCTION OF METALLIFEROUS MINERALS IN THE UNITED KINGDOM DURING THE YEAR 1882.[1]

Description of Ore.	Quantities.	Value.
	Tons.	£
Iron ore	18,031,957	5,779,285
Bog iron ore	5,872	1,957
Tin ore	14,045	805,847
Copper ore	52,810	206,738
Lead ore	65,001	592,610
Zinc ore	32,539	93,571
Iron pyrites	25,403	14,459
Cobalt and Nickel ore	38	241
Manganese ore	1,548	3,907
Wolfram	58	747
Arsenical pyrites	12,564	11,614
Total value of metalliferous minerals		£7,510,976

FRANCE.

Metal mining in France is of very ancient origin, as the Gauls were familiar with gold, silver, lead, copper, tin, and iron previous to the Roman conquest of the country. Under Roman government metalliferous mines were extensively worked, but at the time of the Northern invasion they were generally abandoned. At a later date mining was resumed by the Saracens, who carried on that industry in the Pyrenees and in various other districts, but it was not until nearly the end of the eleventh century that the mines of France assumed any distinctive importance. In the thirteenth century mining was again generally abandoned in consequence of long-continued wars, and the mines were not re-opened until the commencement of the sixteenth century. During the Thirty Years War operations were again arrested, and it was not until the beginning of the eighteenth century that some prosperous mining undertakings were carried on in Brittany, in the Pyrenees, and in Central France. This prosperity of mining enterprise was however only temporary, and it is somewhat

[1] "Mineral Statistics of the United Kingdom for the year 1882, prepared by Her Majesty's Inspectors of Mines." London, 1883.

remarkable that, with the exception of those of iron ores, comparatively few of the metalliferous deposits of France are rich enough, and at the same time sufficiently easy of access, to repay the expenses of working.

France has no valuable gold mines, but the sands of some of her rivers are to a small extent auriferous. The only vein known to contain gold in appreciable quantities is that of La Gardette, in the Department of Isère, which is from two to three feet in width, and is enclosed in gneiss. Gold was discovered in this locality in the year 1700, and workings were intermittently carried on up to 1841, but the aggregate amount of the precious metal obtained was very small. The Rhine, until recently forming for some distance the eastern boundary of France, for centuries yielded small quantities of gold, and, according to a report of Réaumur presented to the Academy of Sciences in 1718, its sands had been chiefly worked between Strasburg and Philippsburg. The gold of the Rhine in the vicinity of Strasburg formerly belonged to the magistrates of that city, who farmed out the gold-washing on a royalty, but in the year referred to they only received some four or five ounces as their proportion of the annual produce. In the year 1846 Daubrée made an exhaustive report to the Academy of Sciences in which he states, that the gravels most commonly worked were those deposited below sand-banks or gravel islands which have been eroded by the river; and that the gold is chiefly concentrated in the coarser gravels which have been freed from silt and fine sand by the action of currents.[1] The gold usually occurs in the form of minute scales, and is constantly accompanied by titaniferous iron ore, the amount of which is proportionate to the richness of the original sand for the precious metal. The workable beds are invariably thin, seldom exceeding six inches in thickness, and the particles of gold are exceedingly small, since the number required to weigh one milligramme varies from 17 to 22, while one cubic metre of gravel contains from 4,500 to 36,000 of such scales. In addition to the auriferous deposits which accumulate in the bed of the stream, Daubrée states that the ancient detritus on its banks, extending from three to four miles in width, also affords an appreciable amount of gold, but that the fine silt free from gravel may be regarded as totally barren.

The sands of the Rhine are still occasionally washed upon a small scale, but it is believed their production was formerly more

[1] *Comptes Rendus*, vol. xxii. 1846, p. 639.

considerable than it is at present. The yield of the year 1846 was estimated at £1,800, the washers usually making from one and a half to two francs per diem, although they occasionally realized from ten to fifteen francs. After a very careful study of the whole question Daubrée arrived at the conclusion that, by the aid of proper appliances, these sands might possibly, at that time, be treated with advantage. Some of the operations were evidently capable of improvement, since the washing was entirely conducted by manual labour, although the motive power of the river itself might, if applied to a dredging machine, be easily made to remove the richer gravels and to deposit them at the head of a properly arranged sluice. Although the application of machinery might doubtless in this and other ways be made to materially lessen the expense of washing the sands of the Rhine, the yield of gold is so exceedingly small that it is nevertheless doubtful whether by any known method of treatment satisfactory results could be obtained.

Several localities in France have from time to time afforded small quantities of gold, the River Ariége (*Aurigera*) being said to have derived its name from its auriferous sands. The washing of these up to the close of the fifteenth century is stated to have yielded nearly a hundred pounds weight of the precious metal annually. Small quantities of gold have been also sometimes obtained by washing a conglomerate of Carboniferous age, in the vicinity of Bessèges, Département du Gard, where traces of gold occur in the quartzose pebbles of the Millstone Grit.

The production of gold in France during the year 1880 is officially stated to have been 31 kilogr. or 996½ oz., but the ores from which it was obtained were probably, in part at least, derived from foreign sources.

Iron ores are produced in thirty-three of the French departments; that of Meurthe-et-Moselle having in the year 1880 furnished 58 per cent. of the total production of the country.

The yield of each of the following most productive departments exceeded in that year 50,000 tonnes, namely:—[1]

	Tonnes.
Meurthe-et-Moselle	1,658,000
Haute-Marne	195,000
Ardèche	190,000
Saône-et-Loire	160,000
Cher	102,000
Pyrénées-Orientales	98,000
Gard	88,000
Isère	53,000

[1] "Statistique de l'Industrie Minérale en France et en Algéria Année, 1880," p. 33. One tonne = 1,000 kilogr.

The following table gives the total production of iron ores in France during the year 1880, together with the proportional weights of the different varieties obtained :—

Nature of Ores.	Tonnes.	Percentage.
Oolitic ores	1,841,000	64·1
Other hydrated oxides in grains, geodes, &c.	554,400	19·3
Red hæmatite	242,400	8·4
Brown hæmatite	107,500	3·7
Spathose iron ores	103,400	3·8
Clay ironstone	5,800	
Magnetite	19,700	·7
Total	2,874,200	100·0

Copper mines are worked in the departments of Var, Gard, Basses-Pyrénées, and in Savoie, but their aggregate production of merchantable ore during the year 1880 amounted to only 550 tonnes. Zinc ores are produced in various parts of France, but the most important are those of Saint Laurent-le-Minier, Gard, which yielded about one-half of the annual production of the country.

Burat[1] divides France into five metalliferous districts, namely: —the promontory of Brittany, bounded by a line extending from Contentin, passing near Alençon and Angers, and terminating in the vicinity of Parthenay; the mountainous range of the Vosges, forming a kind of island surrounded by sedimentary rocks; the great plateau of Central France; the Pyrenees; and the Alps.

BRITTANY.—Both with regard to its geographical position and its geological constitution, Brittany closely resembles Cornwall, being like it a region largely composed of clay slates broken through by granite, traversed by dykes of porphyry, and penetrated by masses of serpentine. In spite, however, of these analogies the metalliferous deposits of the two countries are of very unequal importance. In Brittany the tin veins of Cornwall are but feebly represented, copper lodes do not exist, and mines of argentiferous galena, similar to those of North-Western Cornwall, are not very actively wrought.

Oxide of tin has been found in small quantities in various localities particularly at Pyriac, two and a half miles west of the mouth of the Loire, and at the Moulin de la Villeder, Morbihan. At Pyriac the clay slate is in contact with the granite, and at their point of junction there is an alternation of schistose and granitic or gneissic rocks containing oxide of tin, which occurs either disseminated through thin veins of quartz or in the form of small

[1] "Géologie Appliquée," 3rd ed. part i. p. 364.

concretionary masses. A considerable amount of prospecting was carried on at this place in 1818, but although about 10 cwts. of tinstone were collected no workable or regular deposit of that mineral was discovered.

At the Moulin de la Villeder, near the rock Saint-André, a vein of stanniferous quartz is enclosed in granite. Its direction is N. 34° W., and the veinstone assumes a greenish colour wherever oxide of tin is present. In addition to cassiterite this vein contains mispickel, topaz, and emerald, and at various places in the district the alluvium is to some extent stanniferous.

Poullaouen and Huelgoët, situated near Morlaix, in the Department of Finistère, were for a long time the most important lead mines in France, but have not been in active operation since the year 1866. The workings, first commenced in 1729, were chiefly confined to two principal lodes, both of which traverse clay slates of Silurian age. The main lode at Poullaouen was opened for a length of 750 fathoms and to a depth of about 100 fathoms. Its width is very irregular, varying from a few inches to twenty-five fathoms. Its average breadth, which is somewhat difficult to determine, as it has neither selvages nor well-defined walls, may be taken at about six feet, while its course is nearly north-west and south-east with a dip of 45° to the north-east. The country rock, consisting of clay slate, associated with quartzite and greenstone, strikes east-north-east and west-south-west, and dips at an inclination varying from 40° to 50° towards the south. The principal ore is argentiferous galena, which is more or less mixed with blende and iron pyrites. These minerals, like the accompanying quartzose veinstone, form a network, in which the galena is more frequently associated with slate than it is with quartz. The strings or threads of minerals, which are often very narrow, sometimes expand to a width of several inches, and frequently separate to again re-unite. Granular ore is sometimes disseminated throughout the slate which forms a portion of the vein-material, and even the wall rock is in some cases similarly impregnated. This lode was considered rich when galena formed one-tenth of the vein-material. The galena is by no means equally distributed throughout the lode, but is found in courses of from 40 to 50 fathoms in length which incline at various angles in the direction of its strike. The ore contains from ·0003 to ·0005 of silver, or from 9 oz. 16 dwt. 0 gr. to 16 oz. 6 dwt. 16 gr. per ton.

The principal lode at Huelgoët, which is on the whole more regular than that of Poullaouen, but nevertheless varies in width from twenty inches to seventy-five feet, has been followed in length for a distance of 500 fathoms and to a depth of about 135 fathoms. Its average width may be taken at about twelve feet, its strike being north-west and south-east, with a dip of about 70° north-east. In addition to argentiferous galena this lode yields gossans, *terres rouges*, carrying a considerable amount of silver, both in the native state and as horn silver. These ochreous ores were mostly treated by amalgamation. The principal veinstone is quartz, which, in addition to galena, contains patches of pyrites, blende, pyromorphite, cerussite, plumbo-resinite, and laumonite. Blende and quartz frequently form ring ores, of which the centre is blende, and fragments of the wall rock are often in the same way encysted by an envelope of silica, as shown in Fig. 27, page 44.

For several years previous to 1857 the average annual yield of these mines was about 240 tons of litharge, 120 tons of soft lead, and 1,280 kilogr. of silver; the whole being of the estimated value of 480,000 francs, or £19,200.

At Pontpéan, near Rennes, a lode yielding argentiferous galena and blende has been worked to a depth of about eighty fathoms and over a considerable length. This vein, which is enclosed in ancient clay slates, runs approximately north and south and is nearly vertical. During the course of the year 1880 the mines at Pontpéan produced 4,184 tonnes of argentiferous lead ores and 1,501 tonnes of blende, of the aggregate value of 1,084,706 francs, or £43,388.

There are likewise veins of galena, which were formerly worked near Saint-Brieuc, but, having gradually become impoverished in depth, they were abandoned in the year 1790, since which period some of them have been re-worked and again abandoned. The other veins of lead ore known to exist in this region are not sufficiently important to demand any special notice.

THE VOSGES.—The deposits of argentiferous galena of this region, which were wrought at a very early period, and yielded considerable returns of lead and silver during the course of the last century, are now almost entirely abandoned. Burat attributes this decay of the mining industry of the Vosges to bad management and a shortsighted policy on the part of former proprietors, and expresses his belief that had the same veins been situated in Saxony or the Harz many of them would have continued in active operation down to the present day.

Numerous veins of argentiferous galena occur in the neighbourhood of Sainte-Marie-aux-Mines, the principal of which is known as the Lacroix Lode, and is celebrated for its great breadth of above sixty feet, as well as for having been worked upon for a length of more than two and a half miles. The lode of Lacroix-aux-Mines traverses the mountain of Saint-Jean at a distance of ten miles from Sainte-Marie, has a north and south direction, and dips, nearly perpendicularly, parallel to the junction of the gneiss with a mass of syenite by which it is separated from the lodes of Sainte Marie.

The lode is chiefly composed of *débris* of the surrounding rocks, in which the distribution of the ore is exceedingly variable. Sometimes it occurs in strings or branches, which occasionally unite to form a lode three feet in thickness, while at others it constitutes a sort of stockwork, or is disseminated in the form of patches or bunches. The ore chiefly consists of argentiferous galena, which is occasionally associated with other minerals, such as pyromorphite and pyrargyrite, native silver being also not unfrequently present. The average yield of the galena for silver is 32 oz. 13 dwt. 8 gr. per ton; and the works, which were carried on by means of an adit driven at the level of the natural drainage of the country, were never extended much below the adjoining valley. This vein is stated to have been at one period extremely productive, and large quantities of native silver were found in the upper levels. The production in the year 1756 is said to have been 1,200 tonnes of lead and 46,939 oz. of silver.

This lode was discovered in 1315, and in 1581 it was worked by the Duke of Lorraine with very profitable results; but the wars which took place towards the end of the century caused a suspension of the operations. In the year 1721 a lease of the mine was granted to a company which, after working it inefficiently during a period of eighteen years, again abandoned it. A new company re-opened it in 1755, but although they obtained considerable quantities of rich ore they were unable to repair the damage resulting from the unskilful working of their predecessors. In 1777 the ore was extracted without any proper regard to the support of the ground, so that the workings finally became crushed, and a company which commenced operations in 1785, and which during many years worked with intelligence and assiduity, was unable to put the mine into a satisfactory condition. The difficulties were subsequently increased by the revolution of 1789, and in the year 1808 the right to cut wood for fuel in the neighbouring forests, granted them by the Duke of Lorraine, was rescinded by Napoleon I. The mine was ultimately abandoned in 1816. A concession for Lacroix-aux-Mines was again granted in 1822, but all operations ceased in 1833, and they have not since been resumed.[1]

In the immediate vicinity of Sainte-Marie-aux-Mines the lead veins are smaller, and traverse the gneiss in an east and west direction. Two of these, namely, the Surlatte and the Espérance, have been worked upon for a considerable distance, but the galena contains only about one-half the proportion of silver which is present in that from the Lacroix vein.

At Giromagny, on the southern flank of the Vosges, is another group of metalliferous veins, which have from time to time been worked to more or less extent. These veins, of which the course is nearly north and south, are enclosed in porphyries and clay slates.

At Saint-Jean-d'Auxel there are three lodes which were formerly worked upon a somewhat extensive scale, some of the excavations being still open in 1779. Metalliferous veins are found almost always wherever porphyries and syenites are visible. At Plancher-les-Mines, at Fresse, and at Ternuay in the Haute-Saône, there are quartz veins which, in addition to calcite and fluor spar, contain pyrites, grey copper ore, and argentiferous galena.

The metalliferous veins of the Vosges may be divided into two classes. The first, running nearly north and south, comprehends the principal lodes of argentiferous galena; while the second, coursing nearly east and west, includes, in addition to lead veins, a large number of quartz veins containing calcite, fluor spar, fahlerz, argentiferous galena, argentite, arsenical cobalt, native arsenic, and pyrites which is occasionally auriferous.

At Sainte-Marie-aux-Mines the Phaunoux vein, which was worked at the same time as the Surlatte and the Espérance lead lodes, yielded argentiferous grey copper ore with arsenical cobalt and native arsenic. The Phaunoux, Surlatte, and Espérance lodes belong to the class of which the direction is nearly east and west.

The Selschaft, Saint-Martin, Sainte-Barbe, and Saint-Urbain at Giromagny yielded argentiferous grey copper ore with sulphide of silver and galena disseminated throughout the veinstone in such a way as to require stamping. At Saint-Daniel, on the other side of the Auxelle Mountain, the slimes resulting from the

[1] H. Landrin, "Du Plomb, de son État dans la Nature, de son Exploitation, de sa Métallurgie et son Emploi dans les Arts," Paris, 1857, p. 151.

treatment of the ores contained copper, lead, and a considerable amount of silver. The mountains separating Giromagny from Plancher-les-Mines are traversed by numerous veins running in almost every direction, all of which contain ores of lead, copper, and silver.

In addition to veins yielding the metals above enumerated, the Vosges contain extensive deposits of iron ore. The most important of these is situated in the mountain of Framont, near the contact of a central mass of porphyry with beds of schist and limestone, which it has uplifted and displaced. In this locality red hæmatite mixed with specular iron ore forms a contact vein of from fifteen to thirty feet in thickness surrounding the central mass of porphyry. The limestone, where it comes in contact with this ore, is either converted into crystalline marble or transformed into granular dolomite.

A large number of metalliferous deposits, in addition to those above enumerated, occur in various parts of the Vosges, but they are seldom of an extensive character, and with but few exceptions they are unworked.

CENTRAL FRANCE.—The plateau of Central France, which comprehends the mountains of Forez and Auvergne, as well as those of the Cévennes and Lozère, contains numerous veins of argentiferous galena, some of which are extensively worked and have yielded large quantities of lead and silver.

At present the most important argentiferous lead mine in France is Pontgibaud, which is situated at the foot of a range of mountains four and a half miles north-west of Clermont, Puy-de-Dôme, and on the road from that town to Limoges. The rocks traversed by the lead lodes in the vicinity of Pontgibaud are principally granite, gneiss, and schists, often broken through by dykes of porphyry, and frequently covered either by sheets of basalt, beds of cinder, or by flows of lava, from neighbouring extinct volcanoes. Two extensive lava-flows, issuing respectively from the Puy-de-Louchadière and the Puy-de-Dôme, unite near the smelting-works at Pontgibaud, and flow together for a considerable distance; while the River Sioule, which is in the immediate vicinity of the works, flows over a sheet of basalt, which on one of its banks is seen to be directly covered by a flow of lava. These volcanic phenomena, formerly so active, are now represented only by occasional mineral springs, and by an abundant evolution of carbonic acid gas, which occasionally presents a not inconsiderable obstacle to the working of some of the mines.

The veins, of which there are several, have a general direction of about N.E. and S.W. The veinstone of one only of these lodes consists chiefly of quartz, that of all the others being principally composed of a felspathic rock, differing but slightly from the enclosing granite and gneiss.

Near the surface the veinstone, as well as the enclosing rock, is usually more or less decomposed, but at greater depths they become gradually harder and less altered. The lodes frequently contain sulphate of barium, which is often well crystallized, but this mineral is only plentiful near the surface, and almost entirely dies out in depth. The quartz, which often accompanies the galena, is on the contrary more abundant in the lower levels than nearer the surface.

The felspathic quartzose rock, which constitutes the most abundant veinstone, usually contains less mica than the surrounding granite; but this is not invariably the case, particularly in large expansions of the veins, where the ore often appears disseminated in a somewhat decomposed granite. It is also to be remarked that the sterile parts of the lodes are usually better defined, and are more frequently separated from the country rock by clay selvages, than are the more metalliferous portions of the same vein.

The galena, which is always rich in silver, assumes various forms: sometimes it is extremely fine-grained like steel, at others it is lamellar, and less frequently it is found in the form of well defined crystals. The ore seldom forms bands parallel to the walls, but is usually disseminated through the veinstone either as small branches or as detached grains; the country rock likewise often contains branches and spots of galena.

The galena is often accompanied by a little blende or iron pyrites, and, less frequently, by patches of fahlerz. The mineral is chiefly found in shoots which, without having a large horizontal extension, hold downwards to considerable depths, while the intervals of unproductive ground are generally much longer than the courses of lead ore. There are also cross-courses, composed almost entirely of clay and seldom containing lead ores, which traverse and displace the metalliferous lodes.[1]

Ancient workings, respecting the origin of which there are not even any traditions, afford evidence of the mines of Pontgibaud having been somewhat extensively wrought at a very early date.

[1] Rivot and Zeppenfeld, *Annales des Mines*, vol. xviii., 1850, p. 153.

A memoir by M. Guenyveau, published in 1822, furnishes some very interesting details relative to the history of early mining in the neighbourhood of Pontgibaud.[1]

The most ancient documents relative to these mines are letters patent granted 17th September, 1554, to the Seigneur de Lafayette, by Henry II., for working the mines of Combes, Roure, and Barbecot. In 1739 the working of these mines was undertaken by M. Dulude of Pontgibaud, and afterwards by the Chapades Company. In 1781 the works were recommenced by MM. Engelvin and Dulac, who formed an association called the Compagnie du Lyonnais. The operations were carried on until 1792, when the works were abandoned in consequence of political events which caused many members of the association to leave the country. From this time the mines remained unworked until 1826, when they were re-opened by M. de Pontgibaud under the direction of the celebrated M. Fournet, who was succeeded by M. Loupot, who remained in charge of the works until the year 1844. In 1836 the mines were purchased by a *Société en Commandite* bearing the title of Alphonse Pallu et Cie., who in 1852 transferred them to an English company, who entrusted the technical management to Messrs. John Taylor and Sons of London. Since that date the mines and smelting works have progressed steadily and satisfactorily, and have in the aggregate yielded large profits. Their present greatest depth (1883) is 110 fathoms, the workings being confined to the mines of Roure, St. Denis, Mioche, La Brousse, and Pranal.

The quantity of ore treated at the smelting works during the financial year 1879-80 amounted to 3,097 tons, of which 2,806 came from the mines of Pontgibaud, while the remaining 291 tons were purchased ores.

These ores yielded:—silver, 174,012 oz., value £41,359; lead, 1,424 tons, value £21,469. The quantity of ore smelted and desilverized during the year 1880-81 was 2,902 tons, of which 2,717 tons were the produce of the Company's own mines, and 185 tons were purchased.

The production of the smelting works was:—silver, 158,340 oz., value £39,952; lead, 1,044 tons, value £16,233.

The lead ores of Pontgibaud, although variable in this respect, are always rich in silver, usually contain above one ounce of that metal for each unit of lead present, so that 50 per cent ores will contain above 50 oz. of silver per ton, and the lead flowing from

[1] *Annales des Mines*, vol. vii. 1822, p. 161

the smelting furnace will always yield considerably above 100 oz. of silver per ton.

The mines of Vialas and Villefort are situated in the department of Lozère, but the veins of the first-named locality only are now worked. The granitic mass of Lozère is on all sides surrounded by mica schists, which gradually pass into clay slates, and constitute the true metalliferous rocks of the district. These schists are in some places covered by more recent rocks, such as the Coal-measures of Grand Combe and Bessèges, and occasionally by strata of Triassic, Liassic, and Oolitic age. All the veins which have been explored in these schists have been found to continue down into the granite, where they become contracted into mere strings of from half an inch to an inch in width, and which consequently do not admit of being advantageously worked. In many cases lodes which, at the surface, appeared only as narrow fissures containing little or no mineral, in depth produced considerable quantities of argentiferous galena, while, on the other hand, comparatively rich outcrops of lead ore have gradually dwindled and finally disappeared.

The different groups of veins and fissures found in the neighbourhood of Vialas are, in the following table, given in the order of their respective ages, as indicated by their intersections; the first-mentioned being the oldest.[1]

Group.	Direction.	Group.	Direction.
1. Veins . . .	E. 11° N. True.	6. Veins . . .	N. 26° E. True.
2. „ . . .	E. 33° N. „	7. „ . . .	E. 18° N. „
3. „ . . .	N. 41° E. „	8. „ . . .	N. 40° W. „
4. „ . . .	W. 20° N. „	9. Fissures . .	N. 18° W. „
5. „ . . .	S. 3° E. „	„ [2] . .	S. 33° E. „

In addition to the above, considerable displacements of the country rock have taken place from east to west.

The veins of Group 1, which are not numerous but tolerably wide and well defined, dip towards the south at an angle varying from 75° to 80°.

Lodes belonging to Group 2 are the most important of those which occur in the vicinity of Vialas, comprehending as they do all the more productive metalliferous deposits of the district. They all dip to the south at angles varying from 60° to 80°, but it would be difficult to state, even approximately, their average

[1] Rivot, "Sur les Filons de Galène Argentifère de Vialas," *Annales des Mines*, vol. iv. 1863, p. 329.

[2] The relative age of these fissures not being determined, it has not been thought desirable to assign them a number.

width. The barren portions of these lodes are usually very narrow, while their richer parts are often without well-defined walls, as the ore either extends into the enclosing schists, or the lode is composed of a number of reticulated veins at varying distances apart.

The veins constituting Group 3 are not numerous, and are of but little importance excepting as regards their displacing other lodes; they dip towards the south at angles varying from 70° to 80°.

The veins of Group 4 are generally larger, and more distinctly defined, than any of the others; they are seen in all the schistose region surrounding the central mass of granite, and often appear as quartzose outcrops, standing forty-five feet above the surface of the ground, and may be followed for long distances.

Veins belonging to Group 5 are very numerous, and some of them have been well exposed in the various workings. They dip at an angle of 85° towards the west, and have smooth and well-defined walls. They vary in width from two to seven feet, and are usually composed of a carious quartz, which is generally white, but is sometimes stained brown by oxide of iron. These veins do not, as a rule, contain any ore excepting at their intersection with others, but in such situations deposits of galena rich in silver sometimes occur.

The veins belonging to Group 6 are numerous. They dip towards the south-east, and are composed of spongy ferruginous quartz. They have usually well-defined walls, which are sometimes separated from the veinstone by a selvage of plastic clay of a dark colour.

Heavy spar forms the exclusive veinstone of Group 7, the veins of which dip towards the south.

The veins of Group 8 dip towards the south, are chiefly composed of comminuted schists, and are usually barren.

Group 9 is represented by a number of nearly vertical fissures, without slickensides, which divide all the veins of the preceding groups, and sometimes displace them for a distance of about a yard. Some fissures coursing S. 33° E. contain no filling of any kind, dip west at an angle of about 45°, and appear to be of no particular importance.

The period at which the mines of Vialas were first worked is somewhat uncertain, but that they were wrought at an early date is evident from the fact that some of the more ancient excavations bear evidence of having been made by the aid of fire.

The more modern workings were commenced in 1781 upon some productive outcrops which about that time were accidentally discovered, and smelting works were established at Villefort for the treatment of the argentiferous galena produced in the immediate neighbourhood. In 1827 these mines were abandoned, and the works were removed to Vialas.

The annual production of silver in this establishment has generally varied between 22,500 and 32,150 oz., but in 1856 it reached 48,225 oz. In 1861 and 1862 the yield was 61,278 oz. and 62,049 oz. respectively.

During the latter year the production of work lead was 367 tonnes; and 1,930 kilogr. of silver were obtained from 370 tonnes of lead. The work lead consequently contained 167 oz. of silver per tonne.

In 1880 the only mine besides Vialas working in the Department of Lozère was Ispagnac, the yield of both during the year being returned at 577 tonnes of prepared argentiferous lead ore, of the estimated value of 177,667 francs or £7,106.

Numerous metalliferous deposits occur in the valleys of the Aveyron and Tarn, in the neighbourhood of Villefranche and Milhau. These usually contain argentiferous galena, accompanied by calamine and by various ores of copper. The mines of this district were worked by the Romans, and in the tenth and sixteenth centuries are said to have yielded considerable amounts of silver, resulting in the establishment of mints for the coinage of that metal at Rodez and at Villefranche. These mines are stated to have been abandoned in consequence of the religious wars by which the country was devastated from 1560 to 1597.

The ancient copper mines of Chessy, situated in the Department of the Rhone, ten miles north of Lyons, on the left bank of the River Azergue, are famous for having furnished the magnificent specimens of blue carbonate of copper, hence known as *chessylite.* Crystalline and metamorphic rocks here occur in immediate contact with Bunter Sandstone, which is overlain, with a steep south-easterly dip, by limestones of Liassic age. The more ancient rocks consist of granite, gneiss, mica schist, and aphanite, known to the miners as "hornstone," which predominates in the immediate neighbourhood of the metalliferous deposits. The general mode of occurrence of copper ores at Chessy will be understood on referring to Figs. 58, 59, after drawings by M. Raby, formerly manager of the mines.[1]

[1] *Annales des Mines*, vol. iv. 1833, p. 393.

Four different kinds of copper ores were formerly obtained from this locality, namely, yellow copper ore mixed with iron pyrites containing from 15 to 20 per cent. of copper, known as

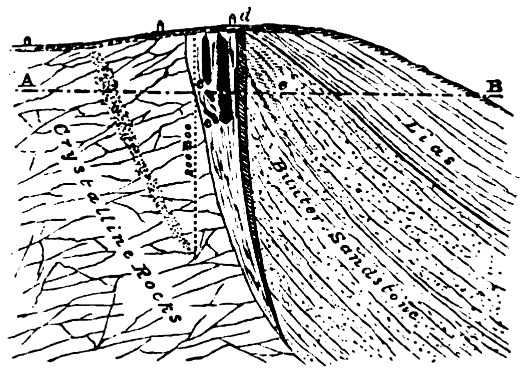

FIG. 58.—Copper ore deposit, Chessy; transverse section on C, D, E, F.

mine jaune; melaconite intimately mixed with iron pyrites; yellow copper ore, silica, and various other substances, known as

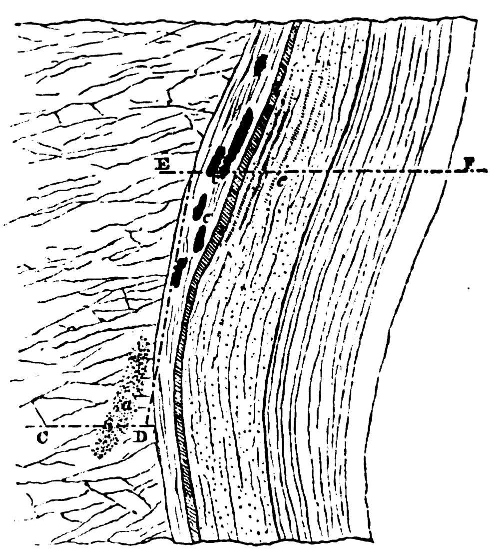

FIG. 59.—Copper ore deposit, Chessy; horizontal section on A, B.

mine grise or *mine noire;* cuprite, *mine rouge,* disseminated in the form of laminæ and crystals through a red clay; azurite or blue carbonate of copper, *mine bleue,* found either in veins or disseminated in irregular concretions, and when crystallized containing about 70 per cent. of copper.

The *mine jaune*, consisting of mixed sulphides of iron and copper, marked *a* Figs. 58, 59, was found only in the aphanite, where it formed one large mass which, commencing a few yards only below the surface, extended downward to a depth of 100 fathoms. This deposit was flattened in the direction of the bedding of the Mesozoic rocks, towards which it dipped at an angle of 66° with the horizon. Its greatest thickness, taken at a depth of sixty feet from the surface, was about forty-six feet, and its total length 100 fathoms. This mass of mineral was on all sides surrounded by more or less decomposed aphanite, from which it was not separated by any wall or selvage, the two materials being intimately mixed, and the one becoming gradually replaced by the other.

The *mine grise*, *b*, and *mine noire*, *c*, were found in the form of separate rounded masses enclosed in a wedge-shaped bed of greyish rock, which is interposed between the aphanite on the one side, and the sandstone on the other. The largest of these ore masses occurring in this rock, which has perhaps been produced by the decomposition of aphanite, had a length of 36 feet, a breadth of 9 feet, and a depth of 15 feet.

The *mine rouge* was found disseminated in a vertical bed of plastic clay of a reddish colour, *d*, where it was sometimes associated with a small quantity of native copper. This deposit commenced at the same level, and ceased at the same depth as that of the blue carbonates.

The carbonate of copper, *mine bleue*, represented in the woodcuts by the lines of shading, *e*, was found only in the beds of sandstone and in certain veins of clay with which they alternate. It usually occurred either in the forms of geodes lined with crystals, or in that of nearly solid masses having, in the majority of cases, a small cavity in their centre, but less frequently it was concentrated in veins parallel to the stratification of the sandstone. The largest of these veins had a horizontal length of 300 feet, a thickness of eighteen inches, and a depth upon its underlie of about ninety feet.

With regard to the origin of these ores M. Raby remarks that all the copper found at Chessy was, without doubt, originally deposited in the state of *mine jaune*, and probably at the same time as the more ancient rocks. Some of the masses of this ore were subsequently converted by chemical action into *mine grise* or *mine noire*, while others were decomposed and by the re-arrangement of their elements gave rise to the formation of *mine rouge* and *mine bleue*.

In the neighbourhood of Saint-Bel, a village six miles south-west of Chessy, situated on the Brevenne, a small river flowing towards the north-east, there were formerly copper mines somewhat similar to those once worked in the last-named locality. The granite in this district changes into gneiss, which soon disappears to give place to mica schist accompanied by clay slates and aphanite. The latter rock forms beds of very varying extent, some of which are, however, as much as ninety feet in thickness, and alternate with beds of mica schist or clay slate.

These, of which the strike is from north-east to south-west, are very nearly vertical, and associated with them is a parallel bed of a friable unctuous white schist, in which the whole of the copper occurred as thin veins of chalcopyrite following the direction of the planes of stratification. This formation extends for a considerable distance, but is, in many places, covered by rocks of more recent origin. The principal deposits formerly worked in the neighbourhood of Saint-Bel were those of Chevinay, Pylon, Sourcieux, and Gervais. Like those in the Chessy district, all these mines have long ceased to be wrought for copper. The only mining now being carried on in the district is for iron pyrites to be employed in the manufacture of sulphuric acid. The total production of this mineral in France in the year 1880 amounted to 132,288 tonnes of the aggregate value of £83,812; of this amount 93,000 tonnes were obtained from Saint-Bel.

THE PYRENEES.—The Pyrenees abound in deposits of iron ore, which occurs both in the form of siderite and hæmatite; they do not, however, yield any large amount of the ores of the other metals, although mining for lead and copper was formerly carried on at various points.

The most important lead mines at present in operation are those of Sentein, situated in the canton of Castillon, Ariége, at an elevation of 6,888 feet above the sea level, and worked by galleries driven on the course of the lode from the side of the mountain.[1]

The deposit is a contact lode, with Mountain Limestone as the foot wall and schist as the hanging wall. The direction of the mineral-bearing portion is N. 10° E, with a westerly inclination at an

[1] I am indebted to Mr. Ernest du B. Lukis, of St. Fiacre, for the information relative to the Sentein Mines.

angle of about 60°. The lode consists of quartz, calcite, capel, &c., and the upper portion carries a gossan next the hanging wall, which contains rich deposits of carbonates, sulphates and sulphides of lead, together with blende and calamine. The lower portion is a strong lode of quartz, &c., containing galena mixed with blende.

The district at the base of the mountains, reaching to an elevation of from 3,280 to 3,936 feet above sea level, consists of schist. This is covered by limestone varying from 164 feet to several hundred feet in thickness, above which is an irregular layer of schist. The ore-bearing lode, which occurs between the schist and the limestone, may be traced for a great distance along the ridge of the mountains following the horseshoe curves of the strata. Above the schist is another limestone which, with quartz, forms the peaks of the mountain. This quartz does not contain gold, although the galena sometimes gives as much as 3 dwt. of fine gold per ton.

The lowest strata of schist contain poor lodes of copper pyrites and some carbonate of copper, with bands of ironstone. Hæmatite and deposits of blende are met with near the summit of the range, but are not workable.

The galena, enriched by mechanical means to 78 per cent. of metallic lead, gives 580 grammes of silver or about 18½ oz. per tonne. The carbonate of lead, at 72 per cent. of metallic lead, but containing a little sulphide, yields 800 grammes of silver per tonne. Very little silver is lost during the mechanical treatment of these ores. The blende contains no silver.

The annual production of the mines varies very much, owing to the inclemency of the weather at the altitude at which they are situated. In 1882 there were sent to the dressing floors about 11,500 tonnes of crude ore, giving about 850 tonnes of marketable lead ore and about 1,100 tonnes of marketable blende.

About ten miles from Aulus, Ariége, may be observed remains of some ancient excavations, together with outcrops of metalliferous deposits containing iron pyrites with traces of argentiferous galena and blende, but consisting principally of calcite and fluor spar. This mine, which is known as the Argentière, has been repeatedly worked at various periods, but has now been abandoned for many years. Among the ancient mines sometimes spoken of in this part of France are those of Baigorry, Basses-Pyrénées, which formerly yielded a small quantity of copper.

The most important iron deposits are probably those of Rancié, near Vicdessos, which some years since kept no less than fifty Catalan forges constantly supplied with suitable ore, and are known to have been worked during a period of more than six hundred years. The enclosing rocks are white granular limestone, a less crystalline grey calcareous rock, and argillaceous schists of Jurassic age. The iron deposits of Rancié occur in nearly vertical beds, one of which is so permeated by brown and red hæmatite, spathose iron ore, and occasionally with oxide of manganese, that ore frequently becomes the prevailing material. The limestones are often much coloured by oxide of iron, and are traversed by numerous veins of pure hæmatite containing druses lined with concentric layers of brown and red oxide of iron. This bed, which has an average thickness of about sixty-five feet, can be traced from the bottom of the mountain to its summit, a height of 1,970 feet, while its inferior limit has never yet been reached. The parallelism of this formation with the surrounding strata caused them for a long time to be regarded as being of contemporary origin, but M. Dufrénoy, who some years since examined this deposit, inclined to the opinion that the deposition of iron ores took place subsequently to that of the enclosing strata.

The Canigou deposit exhibits the mode of occurrence of spathose iron ores upon a still larger scale. A mass of granite has here pierced the surrounding stratified rocks, and along an ellipsoidal zone, having a maximum diameter of about ten miles, where the two different rocks come in contact with one another are numerous deposits of carbonate and oxide of iron. In this way the mines of Batère, Rocas-Negros, Droguère, Olette, Fillols, Vellestavia, Saint-Martin, &c., are arranged around the central mass of granite. Numerous deposits of iron ores and of other metalliferous minerals occur in the Pyrenees, but they are generally of limited dimensions and are, for the most part, unworked.

THE ALPS.—Numerous deposits of iron ore are worked in the French Alps, but mining for the ores of other metals is not carried on upon a large scale.

The small but well-cultivated plain which lies below Bourg D'Oisans, Isère, is traversed from south-east to north-west by the River Romanche, and from east to west by the Olie, one of its tributaries. Immediately north of the confluence of these two streams the mountains of Chalanches, a spur of the Alpine chain, rise to a height of 6,700 feet above the plain, or about 9,000 feet above the level of the sea. The upper portion of this range is composed of a gneiss in which felspar and hornblende are always abundant, although quartz and calcite are sometimes also plentiful; while epidote, chlorite, talc and mica are by no means uncommon. This rock, although occasionally fine-grained, more frequently exhibits a coarse porphyritic structure, but in the vicinity of veins the felspar and hornblende, which are elsewhere present in a crystalline form, often graduate imperceptibly into the surrounding ground-mass. The beds present considerable undulations, but their general strike is nearly north and south with a dip towards the west. Near Allemont, on the east, the gneiss is overlain by hornblendic schists.

The discovery in the year 1767 of native silver in this locality by a goatherd whilst in search of a strayed kid, resulted in mining operations which ultimately extended from a height of 4,100 feet to 4,970 feet above the level of the plain, and necessitated the erection of store-houses and dwellings upon the mountain side.

Among the principal lodes which have been, at various times, worked at Chalanches are the following:—[1]

The	Freiddan	bearing	25° S. of E.,	N. of W.,	and dipping	S.W.
,,	Cobalt	,,	30° W. of N.,	E. of S.	,,	N.E.
,,	Siméon	,,	35° W. of N.,	E. of S.	,,	N.W.
,,	Prince	,,	20° W. of N.,	E. of S.	,,	E.
			20° N. of E.,	S. of W.	,,	N.
,,	Hercule	,,	20° W. of N.,	E. of S.	,,	E.
,,	Pirou	,,	25° E. of N.,	W. of S.	,,	S.E. and N.W.
,,	Ste. Hélène	,,	20° W. of N.,	E. of S.	,,	W.

Although these lodes generally measure but a few inches, and average less than a foot in width, they sometimes, for short distances, assume a thickness of as much as 2½ feet. The veinstone very closely resembles the enclosing rock, consisting of the same materials although in different proportions; but containing, in addition, some other minerals. Quartz and calcite are always present, hornblende is perhaps somewhat less plentiful, while chlorite, talc, mica, asbestos and epidote are found only occasionally, and in comparatively small quantities.

Calcite, chlorite, asbestos and epidote are often associated with silver ores, but earthy brown iron ore more frequently accompanies the richer metalliferous deposits. The produce of these veins principally consists of native silver, antimonial silver, freieslebenite, stephanite, pyrargyrite, and occasionally a little horn silver. These minerals are often accompanied by ores of cobalt or nickel, or by both, and various ores of antimony, lead, and copper, are likewise thinly disseminated through the veinstone. The Brisée Vein is a

[1] W. J. Henwood, *Trans. Geo. Soc. Cornwall*, vol. viii. part i. 1871, p. 520.

cross-course which differs less in direction from some of the lodes than, in this respect, they differ from one another. It dips at a higher angle than any of the veins in its vicinity, and is wider than the widest lode in the district. It consists wholly of gneiss, and intersects the Hercule Lode, displacing it about twelve fathoms towards the right.

In the hornblendic schists which succeed the gneiss near Allemont on the south-east, an unsuccessful trial was made on a vein bearing E. 35° N. and dipping towards the west. This measures about eighteen inches in width, and is composed of disintegrated slate and quartz, which is spotted with black oxide of manganese and specular iron ore.

These mines were worked at so great an elevation and at such a distance from every habitation that, even in summer time, the workmen seldom visited their families except on Sundays, and during many of the winter months all communication with their nearest neighbours was entirely cut off by frozen snow-drifts many miles in extent. In spring the steep and ill-made roads were always found to have been rendered almost impassable by avalanches and the general thaw, so that it was necessary to collect at the mines during the summer all materials, tools, food, fuel, and other requisites, for the winter. With the view of reducing to a minimum the cost of carriage, every tool and utensil was shaped upon the plain below, which materially added to the ordinary expenses of working.

The mines of Chalanches have been wrought at various periods, and the ores raised were smelted at Allemont. From 1767 to 1776 they were worked on account of the Government; from 1776 to 1792 by the Comte de Provence, afterwards Louis XVIII., and from 1792 to 1808 again on account of the Government. All subsequent workings which have been undertaken by various lessees have, without exception, resulted unsatisfactorily.

From 1767 to 1803 the quantity of silver extracted amounted to 25,326 lbs. troy, of the value of £83,939, while the general expenditure was £75,636. The net profit realised in thirty-six years was therefore £8,303, equivalent to an average profit of about £230 12s. 9d. per annum.

The mine of Cerésier, Alpes-Maritimes, worked by the Société des Mines du Var, at the present time produces a larger amount of copper ore than any other in France. In the year 1880 the production amounted to 8,000 tonnes of an ore containing about four per cent. of copper in the form of chalcocite. Of this amount, 5,000 tonnes were concentrated as a preliminary to being treated by a process for the extraction of copper by lixiviation.

Excepting the ores of iron, the amount of which has been already stated (p. 233), the production of metalliferous minerals during the year 1880 was as follows:—

PRODUCTION IN FRANCE OF METALLIFEROUS MINERALS OTHER THAN IRON ORES DURING THE YEAR 1880.

Description of Ore.	Weight.	Value.	
	Tonnes.	Francs.	£
Lead and silver ore . . .	13,990	3,229,380	129,175
Copper ore	8,649	149,438	5,977
Zinc ore	12,139	385,422	15,417
Manganese ore	9,652	532,718	21,309
Antimony ore	1,214	243,440	9,737
Iron Pyrites	132,288	2,095,296	83,812
Totals	177,932	6,685,694	265,427

BELGIUM.

Taking into account its limited area, Belgium is, in respect to its mineral wealth, one of the most productive countries of the world. Coal, iron, lead, and zinc ores constitute its chief mineral resources, but, in addition to these, it furnishes numerous valuable mineral substances employed either as building material, for agricultural purposes, or in the arts and manufactures.

IRON.—The iron ores worked in Belgium are hæmatite, limonite, and clay ironstone. The latter is sometimes associated with limonite, but also occurs in independent deposits, which are, however, usually too small to admit of being worked with advantage.

Hæmatite occurs in various conditions and on very different geological horizons, but that which is almost exclusively employed is in the form of oolitic or pisolitic grains. In this state it forms important deposits in quartzose schists which underlie the Coal-measures, and crop out on both sides of the valley containing the coal. The principal iron mines are situated on the north side of the valley where, in the neighbourhood of Vedrin, there are four distinct seams of ore, respectively 2¾ inches, 4 inches, 8 inches, and 11½ inches in thickness, forming with the intercalated schists a bed nearly four feet thick.

At Marchovelette there are five strata of iron ore varying in thickness from 4 to 8 inches; while at Ville-en-Waret there are four beds, two of which vary from 8 to 20 inches in thickness, which with the interstratified schists form a group of about twenty-four feet. At Houssois, near Vezin, the hæmatite attains a thickness of about seven feet. The beds of hæmatite are, at various points, intersected by veins and faults, in the vicinity of which both the ore, as well as the enclosing schists, are not unfrequently impregnated with pyrites, galena, and other metallic sulphides, by which the quality of the former is more or less impaired. The workings along the outcrop on the south side of the valley, are much less important than those on the north. The principal mines are near Huy, where there are two layers of hæmatite having a united thickness of little less than four feet, separated by about one foot of shale. The average yield of these hæmatites is from 35 to 40 per cent of metal.

Limonite occurs in various forms, and in deposits of very different geological age. In the more recent formations it is found in beds, sometimes above three feet in thickness, reposing in depressions in argillaceous sands mainly situated along the banks of the rivers Demer, the two Nethes, and their affluents. The ore from these deposits, which are concretionary and porous, contain about 40 per cent. of iron, with a considerable amount of phosphorus, but they are easily reduced. A siliceous limonite, containing phosphorus, is worked in a Quaternary formation near Quévy, in the province of Hainault. This ore, associated with an argillaceous sand, forms a bed from 3 to 5 feet in thickness, enclosed in a depression in Tertiary sandstone.

The isolated and superficial deposits of iron ore which occur in the province of Luxembourg, and notably at Ruette, Athus, Tœnich, &c., likewise belong to the Quaternary age, and repose upon Jurassic rocks. These ores have apparently resulted from the disintegration of Jurassic rocks during the Quaternary period, and contain from 30 to 45 per cent. of iron.

The Jurassic formation constituting the surface of the southern portion of the Belgian province of Luxembourg, as well as the Grand Duchy of that name and the northern part of Lorraine, is exceedingly rich in iron ore, and furnishes important supplies to the Belgian ironworks. The ore from these localities is known by the name of *minette,* and is a fine-grained oolitic limonite which occurs in extensive deposits in Luxembourg and Lorraine, but less plentifully in Belgium. Near the French frontier the beds of this ore are from 5 to 6 feet in thickness, and the ore contains from 30 to 45 per cent. of iron. The gangue consists principally of calcite, with a little silica and gypsum.

The rocks comprised between the lower quartzose schists and the coal formation, enclose many important deposits of limonite which, up to the present time, have furnished the larger portion of the ore consumed in the Belgian ironworks. These deposits are often very extensive, and the ore always occurs either in masses or veins, but never in the form of beds. The largest production of iron ores in Belgium was in 1865, when it amounted to 1,018,231 tonnes. In 1875 it was only 365,044 tonnes, and in 1881 it was further reduced to 224,828 tonnes.

LEAD AND ZINC.—Lead ores occur in Belgium in the older formations only, where they are found in veins and masses, either alone or associated with blende and pyrites. The veinstone usually consists of calcite, heavy spar and quartz, together with clay and limonite; in massive deposits the gangue is generally a dark clay. Galena, which is found in numerous places, many of which are not of sufficient importance to pay the expenses of working, is frequently accompanied by other ores of lead, such as cerussite and pyromorphite; it is also often associated with blende and calamine.

The most productive lead mine of Belgium is that of Bleyberg, near Moresnet, which is worked upon the only vein in the country, which, after having traversed the Carboniferous Limestone, penetrates the Coal-measures. Considerable masses of lead ore are found along the line of contact of these two formations, but they are worked with difficulty on account of the very large influx of water.

The most important zinc ore of Belgium is zinc carbonate, commonly known as calamine. The hydrous silicate, is of less frequent occurrence, as is likewise the anhydrous silicate of zinc, or willemite. Blende is almost constantly found in association with the other ores of zinc, but, as its metallurgical treatment is more expensive, its value is proportionately less. The ores of zinc, like those of lead, are found in the older formations only, and usually occur either in Carboniferous Limestone, or in rocks of Devonian age, where they form lodes and irregular deposits, associated with galena and iron pyrites. These massive deposits are sometimes several hundred yards across, and the ores in them have usually a gangue of clay, sometimes, however, replaced by limonite, which is occasionally worked as an ore of iron.[1]

The Bleyberg lead vein [2] is enclosed in the Carboniferous Limestone, and in the Coal-measures overlying it. The general direction of the lode is north-west and south-east, forming with the true north an angle of 57°, and with the stratification one of about 115°. It can be recognised for a distance of 3 miles in the Coal-measures, and above 1¼ mile in the limestone. This vein is either vertical, or dips at an angle of from 75° to 80° with the horizon, sometimes to the east and sometimes to the west. No fault or cross-course is known to exist, but it is believed that a change of direction towards the north may have been caused either by a heave or by a bifurcation of the vein.

The filling of the lode, when enclosed in the Coal-measures, is, to a large extent, made up of the *débris* of schists, sandstones, and grits, which, having fallen into the fissure, have partially filled it. When the vein traverses rocks liable to crumble or disintegrate, these fragments are invariably most abundant; but, when the country rock is hard and compact, they are less numerous and leave larger spaces to become filled in another way.

During the time this partial filling of the opening with country rock was actually taking place, or some time subsequently, the fissure and its contents have been subjected to the action of waters containing, in solution, various metalliferous substances, and these have been deposited in the cavities existing between the fragments of the material already partially filling the vein cavity. In this way the filling of the fissure has been partly mechanical, occasioned by the falling in of the sides, and partly chemical, produced by the deposition of minerals from waters holding them in solution. No eruptive rocks have been met with in the district under consideration. The veinstone frequently exhibits a concretionary structure, and where the rocks are hard, and the spaces between the fragments necessarily large, the metalliferous minerals are deposited in ribbon-like bands. These deposits of mineral are composed of alternate layers of blende and galena, the two being but seldom mixed. Alternate layers of this kind have been frequently repeated,

[1] Much information relative to the mineral resources of Belgium has been derived from Mr. J. D. Hague's report on "Mining Industries in Connection with the Paris Exhibition, 1878," Washington, 1880.

[2] See pamphlet published by the Bleyberg es-Montzen Company during the Exhibition of 1878. "Extrait du Catalogue de l'Exposition de l'Industrie minérale belge."

the blende having evidently been the first mineral deposited. The galena carries small quantities of copper, antimony, and silver, with traces of other metals.

Ribboned deposits of blende and galena have been unable to form in those parts of the vein where the whole of the fissure had been already filled with pieces of the country rock, but, in the majority of cases, these fragments have left between them spaces of greater or less dimensions. In such places the blende and galena have taken the exact shape of the cavities left, and have surrounded the fragments of country rock, so as not only to preserve their form but also their sharpness of outline. For considerable distances on the length of the fissure the filling of schist has been so completely disintegrated that it has become filled with unctuous clay, which, being almost completely impermeable by water, has caused certain portions to be almost completely barren. In these portions of the lode blende and galena are sparingly disseminated in the form of minute grains with a few occasional geodes, and with, occasionally a few crystals of various minerals, in strings and cracks. At Bleyberg the influence of the country rock appears to be limited to the effect produced by the amount of material falling into the fissure, and the space consequently left open for the circulation of mineral waters, and for the deposit of ores.

The waters have not introduced into the Bleyberg Lode a sufficient amount of metalliferous material to fill all the cavities remaining open, and these have subsequently been closed by deposits of calcite and silica, removed from the surrounding limestones and schists by the agency of waters impregnated with carbonic acid. Ferruginous minerals have been introduced into the lode in a similar way, and iron pyrites is not unfrequently met with in a compact or cavernous form, in that of stalactites, or as thin strata in geodes, often lined with crystals of blende, galena, or calcite.

In studying the genesis of this lode another phenomenon must not be lost sight of, and that is, that during the progress of the deposition of these minerals, or perhaps afterwards, the vein fissure was several times re-opened. These re-openings of the vein have imparted to the mass movements which not only led to a partial re-arrangement of its contents, but likewise resulted in certain physical effects. In this way there has been a sinking of one or other of the walls of the lode, or a depression or elevation of its filling, giving rise to slickensides and vertical striations of the surfaces. In this way also the regularly foliated deposits of ore have become displaced, turned over, and mixed with those of an irregular and fragmentary nature. Finally, at one period of its formation, the vein fissure, while opening at one side, was gradually closing on the other, which at such points resulted in the crushing of its filling and its reduction to the state of angular fragments. When the re-opening of a vein fissure occurs during the percolation or passage through it of mineral waters, deposits will take place upon the surfaces of the fragments resulting from crushing, and it is not uncommon to find in the Bleyberg Vein a deposit of perfect crystals upon broken crystals of the same or of some other mineral. The metalliferous portion of the lode, together with the various associated minerals constituting its filling, has an average width of nearly three feet; but the enclosing Coal-measures exhibit the effects of the disturbing influences of the rent for a width of above thirty-six feet, within which limits the country rock is crushed, and, to some extent, displaced.

The deposits of substances introduced by the mineral waters before referred to, sometimes occupy one side of this broken ground, and sometimes the other; but their passage can always be traced by the metalliferous, calcareous, or siliceous materials which fill its fissures. On either side of this disturbed zone the rock remains entirely unchanged, and is without any trace of extraneous minerals, even along its planes of stratification.

In the Carboniferous Limestone the filling of country rocks resulting from the disintegration of the walls, no longer consists of schists, sandstones, and grit, but is almost entirely composed of limestone with some blende and galena. The ores here found are precisely identical in composition with those occurring in the Coal-measures; they crystallize in the same dominant forms, and contain similar proportions of copper, antimony, and silver. In the upper part of the limestone there are found, without any recognised order, carbonates of lead, zinc, and copper, which usually enclose kernels composed of the sulphides of the same metals.

The phenomena of the re-openings of the fissure, of the mixing of its filling, and of the crushing by its walls of the veinstone, are seen even more distinctly in the upper portions of the limestone than they are in the Coal-measures. At this point the limestone above the fracture has been eroded into an opening above 1,600 feet in length, 180 in width, and from 180 to 250 in depth.

On the walls of this cavernous space, and on the surfaces of a material resembling geyserite, large quantities of blende and galena were at some time deposited, but by subsequent violent shocks they have become detached and mixed with various other bodies, including fragments of some of the older rocks. Nothing can be more instructive or interesting than these accumulations, in which, although all the minerals and gangues occur in the form of fragments, each individual piece, either by its banded structure or by the arrangement of its crystals, bears distinct evidence of once having formed part of a regular deposit. On the eastern wall of the cavern deposits of blende, galena, calcite, &c., are sometimes found *in situ*, and still adhering to the rock, just as they were left by the waters through the agency of which they were deposited.

A large mass, principally of galena, also occurs at the junction of the Coal-measures with the Carboniferous Limestone, at which point it would appear there was formerly a lake-like depression supplied with plumbiferous waters. In this way was probably produced a large deposit of lead ore, in all respects identical in composition with that obtained from the lode, although forming a solid mass and entirely without any admixture of fragmentary country rock. This mass, which rests upon a somewhat extensive base of the Coal-measure formation, has never been disturbed as in the case of the lode, in which the crushing and mixing of the ores has resulted from the repeated re-opening of the fissure and the consequent movements of its walls. This deposit comes to within twenty yards of the present surface, and is covered by detrital matter from the Coal-measures, and by various shales and rocks of Tertiary age, all stratified horizontally, but unconformably, with the Coal-measures and sandstones.

The amount of water percolating into the Bleyberg mines is unusually large, generally amounting to 7,260 gallons per minute, but, exceptionally reaching 12,000 gallons per minute, which is pumped from a depth of 597 feet. From the date of the formation of the present Company, 1853, up to May 1878, this mine had produced 86,850 tonnes of zinc ores and 86,876 tonnes of lead ores, during which time it had repaid its capital four times over.

The important deposit of calamine at Altenberg or Kelmisberg belongs to the Vieille-Montagne Company, and is situated near Aix-la-Chapelle, in the immediate vicinity of the village of Moresnet. It occurs in the lower strata of the Carboniferous Limestone, which are, for the most part, converted into dolomite, and fills a basin-like depression, of which the longer axis has a length of 600 yards, while its width varies from 200 to 260 yards. This basin of zinc ore and dolomite is, on one side, raised towards the surface and, on the other, dips beneath it, being itself enclosed in soft Devonian schists which come to the surface on both sides. A bed of quartzose dolomite, which carries large quantities of water, separates the two rocks, and in all directions bounds the deposit with great regularity. The ore, which towards the surface is principally composed of very pure calamine with scarcely any admixture of blende or galena, has nearly filled the tilted basin before referred to, and crops out at the surface for a considerable distance.

At Kelmisberg the zinc ore being entirely surrounded by dolomite, nowhere comes into contact with other rocks, and can scarcely be regarded otherwise than as resulting from the gradual transformation of the enclosing dolomite into zinc ore by an exchange of bases effected through the agency of metalliferous waters. This remarkable deposit of ore was most extensively developed near the surface, where it reached a length of 490 yards and a width of 180 yards.

The most productive and most highly concentrated portion of the deposit is situated at the northern extremity of the basin, and is separated from the southern body of ore by a projecting point of dolomite. Towards the south-west the deposit is continuous, but is hidden under a capping of dolomite beneath which it has been followed to a depth of 120 yards. While, at the surface, the ore consisted chiefly of carbonate of zinc, it, lower down, became mixed with hydrated silicate of zinc, which gradually increased in quantity until it eventually formed the larger portion of the ore. Anhydrous silicate of zinc, willemite, has always been found in large masses scattered without any apparent rule throughout the other ores.

The first shafts are said to have been sunk during the fifteenth century for the purpose of supplying calamine to the foundries of Aix-la-Chapelle, the proprietors of which, without any knowledge of the metal it contained, employed it in the manufacture of brass. The largest yield was in 1855, when it reached 137,000 tonnes of ore as it came from the mine, or 50,900 tonnes of concentrated ore. Since the year 1856, the workings have been carried on under ground, and it is known that up to 1878 about a million and half tonnes of first class ore had been extracted from these deposits. The almost chemically pure zinc, which is employed for making *blanc de neige* and for art-castings, is exclusively made at the Moresnet works.

The bed of zinc ore at Welkenrädt[1] occurs between coal-

[1] M. Braun, *Zeitschr. d. d. geol. Gesellsch.*, vol. ix. 1857, p. 354.

shale and Carboniferous Limestone, extending for a distance of more than 120 fathoms along the strike. It dips, like the adjacent beds, at a very high angle, and, with them, has undergone the same folding and faulting. The foot wall, which is in contact with the limestone, consists of either compact, drusy, foliated, shaly, or earthy hydrous silicate of zinc, which, in the higher levels, becomes ferruginous and passes into ironstone, or into a shaly mass with enclosures of limonite. The hanging wall, in contact with the shale, consists of a black clay, which contains nodules and fragments of various metallic sulphides, such as concentric blende, galena, and pyrites. This sulphide-bearing

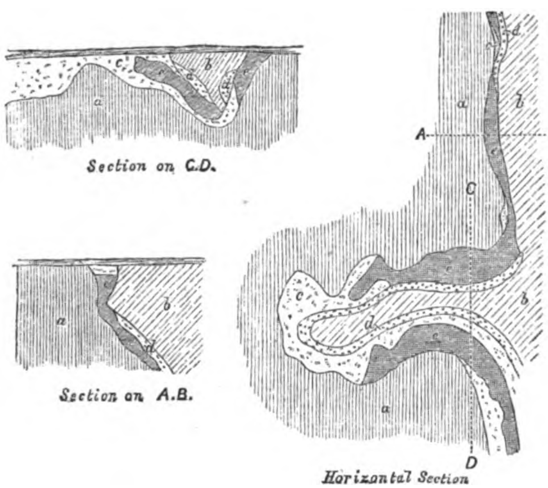

FIG. 60.—Deposit of silicate of zinc; Welkenrädt.

zone which is of much greater extent than that producing zinc ores, is known as the foot wall of the Coal-measures, and is justly regarded as an interstratified deposit. In Fig. 60, after Braun, which represents this deposit, *a* is limestone, *b* shale, *c* clay containing ironstone, *d* shale with galena, &c., and *e* hydrated silicate of zinc.

The production of metalliferous minerals in Belgium has for some years been gradually decreasing, although their importation into that country for metallurgical treatment is very large. This decrease of yield appears to affect almost equally all the ores produced, and it may consequently be of interest to reprint the following table from an official source.[1]

[1] Royaume de Belgique, Ministère des Travaux Publics, *Compte Rendu des Opérations Pendant l'Année*, 1881, *Mines*, p. 5, Bruxelles, 1882.

TABLE SHOWING THE PRODUCTION OF METALLIFEROUS MINERALS IN BELGIUM DURING TEN YEARS FROM 1871.

Years.	Zinc Ore.		Lead Ore.		Iron Pyrites.		Iron Ore.		Total Values.	
	Quantities.	Values.	Quantities.	Values.	Quantities.	Values.	Quantities.	Values.		
	Tonnes	Francs.	Tonnes	Francs.	Tonnes	Francs.	Tonnes	Francs.	Francs.	£
1872	55,177	3,766,000	11,887	1,936,000	40,932	985,000	749,781	7,390,000	14,077,000	563,080
1873	42,582	3,014,000	11,280	2,183,000	35,651	1,060,000	777,469	7,834,000	14,091,000	563,640
1874	43,299	2,707,000	10,894	2,194,000	28,872	778,000	527,300	5,178,000	10,857,000	434,280
1875	42,504	2,878,000	10,567	2,005,000	30,747	807,000	365,044	3,423,000	9,113,000	364,520
1876	37,713	2,555,000	12,422	1,702,000	23,588	566,000	269,206	2,458,000	7,281,000	291,240
1877	44,987	2,505,000	11,542	1,919,000	26,207	639,000	234,227	2,158,000	7,221,000	288,840
1878	45,293	2,479,000	13,477	1,548,000	21,721	523,000	207,157	1,758,000	6,308,000	252,320
1879	42,689	2,145,000	9,384	1,087,000	15,577	324,000	195,212	1,567,000	5,123,000	204,920
1880	38,805	2,242,000	5,434	892,000	7,913	164,000	253,499	1,875,000	5,173,000	206,920
1881	23,553	1,195,000	3,741	657,000	2,965	49,000	224,882	1,817,000	3,718,000	148,720

With the exception of small quantities obtained from surface deposits in the provinces of Limbourg and Antwerp, the iron ores returned for the year 1881 were the produce of Liège, Namur, and Luxembourg.

THE GERMAN EMPIRE.

Germany is undoubtedly the classic land of mining, since it not only comprehends extensive areas of exceptional metalliferous importance, but it was here that the kindred arts of mining and metallurgy were first systematically taught and practised; while at the present time the various mining academies of the German Empire are the resort of students from all parts of the civilized world. The German miner of the middle ages, like his Cornish representative of to-day, was an active pioneer and persevering colonist. In the twelfth century he founded Schemnitz and Kremnitz in Hungary, and three centuries later Schmöllnitz and Kapnik were opened up by miners of the same nationality.

About the middle of the sixteenth century numerous German miners and smelters were induced to settle in Great Britain, Queen Elizabeth, according to Sir John Pettus, having been advised to take this step "from Her observation of the inartificialness of former Ages in this concern, which may be collected from Her sending for and imploying so many *Germans* and other Foreiners (where *Mines* were plentiful and the *Arts* belonging to them), who might put us into the tract of managing ours, in *finding* and *digging* them, and in *smelting* and *refining Metals*." [1]

RHINE PROVINCES, WESTPHALIA, &c.—The ore deposits of this area are exceedingly numerous, and consequently some of the more important only can be noticed.

The oldest account of the occurrence of gold veins in the Eisenberg, near Corbach, is given by Agricola, and it is stated by Brückmann that gold was obtained from this source in the year 1560. Much more recently W. v. Eschwege obtained gold in the form of minute scales from the alluvium of the Edder, but in such small quantities as to render its extraction unprofitable, and moreover he in no case found a fragment of gold adhering to its matrix.

Dieffenbach[2] describes the Eisenberg, near Goldhausen, as being formed of quartzose and clay slates, the former being thinly stratified, much folded, fissured, and contorted. Copper ores, particularly malachite, azurite, chrysocolla and cuprite, occur in these fissures; and the siliceous slate in the vicinity of such ores is soft, much decomposed, and impregnated with calcite. The surfaces of the clefts in this rock are also often covered by incrustations of calcite, dolomite, or spathic iron ore, which are sometimes crystallized. In other cases the cavities in the slate are filled with melaconite, which is sometimes moderately abundant. The siliceous slate in the vicinity of the melaconite and other copper ores, has a cellular texture, and there can be little doubt that this and the other minerals containing copper are the result of the decomposition of pyrites. The gold occurs in the clefts of the quartzose slate, partly incrusting small rhombohedra of spathic iron, which have consequently the appearance of gold crystals, and partly as thin dendritic incrustations upon the surfaces of the clefts. The gold, which is evidently a more recent formation than the crystals referred to, is sometimes covered by small rhombohedra of calcite with rounded edges. The incrustation of gold is at times so extremely thin as to impart a dull brownish colour only to the crystals, and the entire rock, more especially the red clay filling the joints, was found to contain gold. The mode of occurrence of this gold would appear to show that the carbonates of copper and other ores of that metal found in the joints of the slates, are of secondary origin, and that they were derived originally from auriferous pyrites containing copper. Dieffenbach

[1] "Fodinæ Regales," chap. xxiii.
[2] *Leonhard's Jahrb.* 1854, p. 324.

was unable to find any trace of a vein in the siliceous slates, and he was likewise not able to determine whether, at some former period, they were covered by the copper shales which are to be found *in situ* on the flanks of the mountain, and which surround the mines at Goddelsheim.

Alluvial gold, resulting from the disintegration of quartz veins in that district, has been found in the sands of the Goldbach, a tributary of the Moselle, but not in sufficient quantity to repay the cost of extraction.[1]

Numerous veins containing argentiferous galena occur in Devonian rocks in the vicinity of Olpe and Siegen, although but few of them have been more than moderately productive. The most extensive lead mines which have been worked in this district are those of Wildberg and Hideberg, situated upon the same group of east and west lodes. The country rock consists of alternations of schists and slates, with a highly siliceous grauwacke, and the veinstone, which is often to a large extent composed of spathic iron ore, frequently contains, in addition to galena, copper pyrites and blende. The Hideberg Mine is still in operation, but that of Wildberg, which has been worked more or less intermittently from about the fifteenth century, was closed about ten years since. There are likewise lead mines in the neighbourhood of Wiehl, Ründeroth, and Siegburg, besides which, considerable quantities of lead ore and blende have been obtained from mines near Bensberg, nine miles east of Cologne.

The group of lodes extending from Holzappel,[2] on the Lahn, to Wellmich and Werlau, on the Rhine, traverse grauwacke and clay slates of Devonian age, and have usually an E.N.E. and W.S.W. direction, with a general dip towards the S.E., but sometimes towards the N.W. "Talcose clay slates" occasionally form a constituent of this formation and are of frequent occurrence in the immediate vicinity of lodes. These rocks, named by the miners *Weisses Gebirge*, white rock, contain numerous beds and veins of quartz, the latter of which often cross the strata nearly at right angles, and are themselves always intersected by lodes.

The Devonian grauwacke rocks enclose deposits of argentiferous lead ores, as well as ores of copper, zinc, and iron. The iron ore forms regular beds between strata of the schistose rocks,

[1] Nöggerath, "Rheinland-Westphalien," vol. i., 1822, p. 141.

[2] Bauer, *Karsten's Arch.*, 1841, vol. xv. pp. 137–209. Nöggerath "Rheinland-Westphalien," vol. iii. p. 216. B. v. Cotta, "Die Lehre von den Erzlagerstätten." 2nd edit. Freiberg, 1859, vol. ii. p. 143.

superficial deposits of comparatively recent age, or, in the form of spathic iron, is an important constituent of the filling of lodes containing ores of lead, copper, and zinc. The lodes forming the most eastern portion of the group at Holzappel, consist of three distinct leaders, which probably come together in depth; but, like all the other veins belonging to this group, they almost coincide in strike and dip with the bedding of the country rock, and have consequently been sometimes mistaken for metalliferous beds. These lodes have been faulted by two distinct fissures, and have consequently been divided into three portions, of which the most easterly is represented by one only of the three leaders.

The veinstone consists principally of quartz, which sometimes assumes the form of hornstone, with argentiferous galena and blende. Associated with these minerals are tetrahedrite, copper pyrites, spathic iron ore, heavy spar, calcite, and dolomite, which exhibit no regular order of sequence. These ores occur partly as alternating ribbons, but more frequently they are irregularly distributed through the veinstone, which often at the same time encloses fragments of the country rock. Iron pyrites occurs more commonly in clefts in the country rock than in the lodes themselves, which, near the surface, contain numerous products of decomposition, such as cerussite, pyromorphite, cerasine, and anglesite. Blende is represented by smithsonite and goslarite; tetrahedrite by malachite and azurite, and spathic iron ore and iron pyrites by limonite, and by various ochreous iron ores. The ore, although not uniformly distributed throughout the lodes, is concentrated in shoots, bunches, or zones, which incline obliquely to the plane of the lodes, at angles varying from 14° to 20°. These are not only nearly parallel to one another, but also to the line which the stratification of the country rock forms with the planes of the lodes. The lodes are usually separated from the enclosing rock by selvages, and sometimes by friction-surfaces, which are generally grooved parallel to the dip of the shoots of ore. There are no geodes in the veinstone, which is, however, traversed by numerous fissures, which do not extend into the country rock beyond. These are often more or less open, and are lined with crystals which are usually of the same mineral as that on which they are deposited. In this way crystals of quartz are generally deposited upon a quartzose matrix, while crystals of galena are found upon masses of the same mineral. With regard to the influence exercised by the wall rock upon the contents of the veins, there is, at Holzappel, nothing to show that between certain rocks the veins are always rich, and that, when enclosed in others, they are invariably poor; a soft crumbling wall rock is, however, more unfavourably regarded by the miners than a moderately hard one. The walls of the lode are by no means perfect planes, but have been twisted and contorted, and in such cases the parts of a lode cutting through the strata are called *Bänke* by the miners.

The walls of the vein fissures show numerous bends and disturbances, while the country rock is frequently arranged in folds, of which the concentric structure is often very remarkable. The fissures intersecting and faulting these lodes are usually filled with clay, which occasionally contains spheroidal masses of ore, similar to those sometimes found in the veins; and through the agency of these fissures the country rock has frequently become impregnated with copper and iron pyrites. Fig. 61, after Bauer, represents a section of the Holzappel Lode in the

FIG. 61.—Holzappel Lode; Herminen level.

Herminen level, where it varies from fifteen to twenty-five inches in width.

According to A. v. Groddeck the *Weisses Gebirge* of Holzappel, Wellmich and Werlau, the *Lagerschiefer* of Mitterberg in the Salzburg Alps, and the white slates of Agordo in the Venetian Alps, which previously to that time had been described as "talc slates," or as, "rocks resembling talc slate," are *sericite rocks.*[1] He states that analyses of this sericite show that it is a cryptocrystalline potash mica, and that pseudomorphs after felspar, augite, magnetite, and titanic iron ore, are found in the white rock, which must be regarded as an altered eruptive rock, probably diabase. In the white rock of Wellmich are enclosed large crystals of apatite, which he regards as of secondary origin. The variety of white rock called *Lagerschiefer*, and the white slate which encloses

[1] A. von Groddeck, *Jahrb. für Min*, 1883, ii. *Beilage Band*, p. 72.

needles of clay slate, are probably metamorphic rocks resulting from normal clay slates or grauwacke slates. A knowledge of these rocks becomes valuable as opening up new points of view with regard to various important questions relating to ore deposits, since it would appear probable that the sericite slates always occur in association with ore deposits lying conformably with the strata of the surrounding rock. He further remarks that tho deposits of Holzappel, Wellmich, Werlau, and Mitterberg, have, with perfect certainty, been determined to be *Lagergänge* or veins resembling interstratified beds.

The lodes of Holzappel, Wellmich, and Werlau, belong to one *Gangzug* or sytem of veins, and are accompanied by several parallel systems striking N.E., S.W., and dipping S.E.; these are :—

1. The Ems Lode-system.
2. „ Mahlberg „
3. „ Homberg „
4. „ Winden „
5. „ Weinaur
6. „ Holzappel „
7. „ „ „

The lodes of the Ems and Mahlberg tracts are *Quergänge* or true veins. The *Lagergänge* only are accompanied by the "white rock," while it is perfectly unknown in the true veins as well as in the lodes in the neighbourhood of Ems. A. v. Groddeck does not offer an explanation for this, but believes that some relation exists between the formation of the bedded vein and the metamorphic rocks which the miners call "white rock."

In the year 1881 the Holzappel mines produced 2,119 tonnes of lead ore.[1]

The Bunter Sandstone of Bleiberg, near Commern, in the Eifel, in the mining district of Düren, contains a deposit of lead ores which, for extent and productiveness, has no known equal in the world.[2] The variegated sandstone of this district may be divided into two portions, an upper, characterized by finely granular red sandstone and the predominence of clays, and a lower, consisting of coarsely granular sandstones of a bright colour and of thick bands of conglomerate. The lower beds of

[1] *Zeitschr. f. Berg. Hütten. u. Salinen. im preuss. Staate*, vol. xxx. 1882, p. 179.
[2] C. Diesterweg, *Ibid.* vol. xiv. 1866, p. 159.

the lower division of the variegated sandstone contain beds of nodular ore, which are principally worked on the Bleiberg between Call and Mechernich.

Above the Devonian beds there is, first, a bed of red clay containing broken fragments of red grauwacke, and above this a mass of conglomerate, from two to twenty feet in thickness, which fills up all the inequalities of the older rock. This conglomerate forms the floor of the *Knottenflötz* or lower seam of nodules, 15 feet in thickness. Above this is a band of conglomerate, which is covered by the upper seam of ore eighty feet in thickness. In some places other bands of conglomerate are interposed in such a way that four seams are separated from one another by beds of varying depths. Many dislocations occur in these rocks, of which the Greisbach main fissure is the most important. The nodular sandstone of the ore seam is white, dirty white, or yellow, and consists of crystalline quartz granules slightly cemented together. The quantity of cement is very small, and the rock is easily reduced to powder. The ore is associated with sandstones of a white colour; when the colour changes, the ore is usually lost.

The lead ore at Bleiberg occurs in the form of so-called *Knotten* or nodules, and the sandstone to which they belong is known as *Knottensandstein.* Carbonate of copper is present in small quantities. The lead-ore nodules consist principally of galena, and more rarely of cerussite. They are spherical concretions which are scattered through the entire mass of the ore bed. Usually they are smaller than a pea, but in some cases they attain a diameter of one-third of an inch, while on the other hand they sometimes occur as very fine granules only. They consist of quartz grains cemented together with lead ore, with which are associated alumina, lime, and oxide of iron. When galena is present, it is in the form of very finely divided grains deposited between the relatively large particles of sand, and, if examined by the aid of a lens, a crystalline structure is observed. This is of importance as tending to explain the origin of the nodules. When the cementing material is cerussite, it is less distinctly crystallized; in nodules of azurite the cementing copper ore is also in a finely divided state. Nodules of copper ore are most frequent at the Gottessegen Mine. At Berg the copper ore has a considerable extension, but, with its small percentage of copper and the comparatively large amounts of lime and clay present as cement, it is poor and difficult to work. The globular shape of the nodules is best developed when galena is the cementing material; when this consists of white lead or copper ore, the form of the nodules is extremely irregular. The distribution of the nodules in the sandstone is by no means regular; they frequently lie close to one another, and in such cases often grow together, and an irregular ore deposit of great extent is the result. In other cases the nodules are from half an inch to several inches apart. At the Bleiberg the nodules in the workable parts of the beds constitute from 4 to 10 per cent. of the weight of the entire mass. Lead and copper ores are rarely found in actual contact, but the nodules often consist of a centre of galena with an exterior coating of white lead; and sometimes the whole of the lead present is in the form of cerussite. The formation of nodules is not necessarily connected with the presence of ore; since similar concretions frequently occur which do not contain a trace of ore, and are known as *taube Knotten.* In addition to the ores of the conglomerate bed and of the *Knottenflötz,* the variegated sandstone of the Bleiberg contains several iron-ore seams which are worked extensively, and which belong to the upper division containing, as its colour indicates, a larger proportion of iron oxide than the lower one. Dr. A. Gurlt is of opinion that the extension of the deposit and the equable distribution of the ores, indicates that they and the sandstone were formed at the same time.[1]

Galena and white lead ore occur in Bunter Sandstone in a similar way at Saint Avold, west of Saarbrücken.

The Meinerzhagener Bleiberg mine, the most important in the district, in 1881 produced 34,941 tonnes of lead ore.

During the same year the principal districts of the Rhine Provinces produced the following amounts of lead ore :—[2]

	Weight. Tonnes.	Value. £.
Commern district	44,558	249,759
Diez ,,	21,159	101,495
Düren ,,	6,826	39,882
Deutz ,,	4,984	39,101
Ründeroth ,,	4,919	34,633

In 1881 Westphalia produced 8,663 tonnes of lead ore, value £72,107, Hesse and Nassau 21,188 tonnes, value £101,582, and the Rhine Provinces 65,951 tonnes, value £395,305.

[1] *Verhandl. d. naturh. Vereins preuss Rhein. und Westf.*, 1861, p. 60.
[2] *Zeitschr. Berg. Hütt. Salinenw.* vol. xxx. 1882, p. 179.

The Eifel limestones, extending from Elberfeld through Balve to Brilon, are traversed by irregular fissures, which occasionally widen out and are filled with calamine, concretionary blende, galena, and iron pyrites, the latter mineral having often become converted into brown iron ore. The largest amount of zinc ore raised in the Brilon district during the year 1881 was produced at the United Bratenberg and Dörnberg Mines, which yielded 6,037 tonnes of zinc ores, and 3,352 tonnes of lead ore.[1]

Deposits of a similar character occur in the western prolongation of the Devonian limestone near Altenbühren, Rösenbech, and Bleiwäsche, where the deposits, chiefly composed of smithsonite with a little galena, are only of commercial importance when enclosed in Devonian limestone.

Very similar deposits are found in the magnesian limestone of the same age at Gladbach, ten miles east of Cologne, where an irregular bed of lignite is found almost immediately above the magnesian limestone, the surface of which is extremely irregular, containing hollows in which occur the ores of zinc. These consist of calamine, with a little galena, enclosed in clay; and similar deposits of detached fragments of zinc and lead ores are not of unfrequent occurrence in the clay of the lignite formation at a considerable height above the hornstone. Von Huene observes with regard to this deposit that, up to the date of his writing (1852), no particles of blende which had withstood alteration had ever been found in it.[2] At the Frühling Mine, near Altenbrück, two miles east of Bensberg, on the contrary, the blende has only been completely changed into calamine at the outcrops of the deposits, while at greater depths unaltered blende is found enclosed in the larger masses of calamine. The mode of occurrence of the zinc ores at Gladbach and at various other localities in the same neighbourhood, would appear to indicate that they are no longer in their original position, but that they were carried into the basin-like depressions which they now occupy by the mechanical action of the water by which the clays of the lignite formation were deposited. The outlines of these fragments are usually rough and sharply defined, and it therefore appears improbable that they have been transported from any considerable distance. It is consequently quite possible that they may have been derived from the outcrops of lodes containing blende and galena of a similar character to those now worked in the neighbourhoods of Bensberg and Altenbrück.

[1] *Zeitschr. Berg. Hütt. Salinenw.* vol. xxx. 1882, pp. 175 and 180.
[2] *Zeitsch. d. deutsch. geolog. Gesellsch.*, 1852, p. 575.

It is to be remarked that the calamine deposits on the left bank of the Rhine are associated, principally, with Carboniferous limestones, while those on the right bank of that river for the most part occur in rocks of Devonian age.

The largest quantity of zinc ore produced in the Düren district in 1881 was obtained from the Altenberg Mine,[1] belonging to the Vieille Montagne Company, which yielded 17,464 tonnes of zinc ores, against 13,135 tonnes during the previous year.

In the Düren district four mines were working during the year 1881, and together produced 17,121 tonnes of blende and 8,560 tonnes of calamine, of the total value of £22,548.

The copper deposit of the Friedrich-Wilhelm Mine at Berg, near Commern, is, like the lead ores of the immediate neighbourhood, situated in Bunter Sandstone. The bed containing the copper ore strikes from north-west to south-east, dips towards north-east, and has an average thickness of about nine feet. This bed, like the lead ore deposits at Bleiberg, contains the ore for the most part in the form of small nodules. Galena occurs subordinately, and copper and iron pyrites are found in pockets associated with heavy spar. The copper ore nodules consist principally of malachite and azurite, copper glance, chrysocolla, and cuprite. The sand in which the nodules are enclosed consists of quartz fragments united by a cement containing carbonate of lime. This sandstone is more or less ferruginous, and chrysocolla, brown iron ore, oxide of manganese, and calcite occur in its fissures.[2]

The amount of copper which has been furnished by this mine is apparently small. In the year 1853 it yielded 25 tonnes of ore containing from 6½ to 9 per cent. of copper, and 1,508 tonnes in which the percentage of that metal varied from 1½ to 2½. Its most productive year was 1856, when the output was 3,179 tonnes containing from ·75 to 3 per cent. of copper. During the two following years the workings were suspended, but in 1859 the yield amounted to 192 tonnes of ore containing from 1 to 2 per cent. of copper; in 1860 the yield was 139 tonnes of 1½ per cent. ore, and in 1861 the mine was abandoned on account of the large percentage of lime present in the ores.

The Devonian strata in the neighbourhood of Dillenburg,[3] which are traversed by dykes of diabase as well as penetrated

[1] *Zeitschr. Berg. Hütt. Salinenw.* vol. xxx. 1882, p. 175.
[2] W. Jung, *Berg. u. Hüttenm. Zeitung.*, 1862, p. 229.
[3] Stifft, "Geogn. Beschr. d. Herzogth. Nassau," 1831, p. 486.

by pyritous serpentine, consist partly of *Schalstein*,[1] and enclose numerous copper lodes. These veins vary in their strike from north and south to east-south-east and west-north-west, and have usually a considerable dip. The veinstone is principally quartz, clay, brown spar, heavy spar, and calcite. The ore is chiefly copper pyrites, but copper glance, cuprite, malachite, azurite, and chrysocolla are sometimes also present.

The influence exercised by the country rock upon the contents of the veins is very apparent. In diabase the ores are rich in copper but are not very abundant, quartz is the prevailing veinstone, and clay selvages are entirely wanting. On the other hand, in *Schalstein* the lodes have distinct selvages, the veinstone is mainly composed of calc spar, brown spar, and heavy spar, and the ores, although perhaps more abundant, are not usually so rich. The rock in which the veins are on the whole most productive is a decomposed *Schalstein* much stained by hydrated ferric oxide, and which, in the immediate vicinity of the lodes, is often more or less impregnated with copper ores. In the sandstones and Cypridina slate the lodes usually contain but little ore, and the quartz, which under such circumstances is the prevailing veinstone, often merges gradually into the country rock, so that the veins are without sharply defined walls.

Sandberger[2] has determined the presence of copper in the augite both in the diabases and basalts of this district, which may probably explain the origin of the copper contained in the veins. Both galena and blende are sometimes associated with copper pyrites in calc spar, filling fissures in the Nassau diabase, as well as in the copper veins themselves, but they usually occur in very small quantities only, either alone or associated with arsenical fahlerz. Where in depth the diabase becomes compact, the veins are usually without ore, and are represented by fissures principally filled with clay. Senfter has found lead, zinc, and arsenic in the diabases of this region, and it is consequently not improbable that under favourable circumstances these metals may become concentrated in the form of ores.

A group of veins extending from Rossbach to Roth yields tetrahedrite containing silver and sometimes a little mercury, while cinnabar occurs in the copper lode at the Neuermuth Mine at Nanzenbach, and traces of the same mineral are found in

[1] *Schalsteins* are consolidated ash beds, probably resulting from eruptions to which the diabase owes its origin.

[2] F. Sandberger, *Berg. und Hüttenm. Zeitung.*, 1877, p. 390.

the hæmatite which generally occurs in the *Schalstein* of the district.

A considerable number of veins very closely resembling one another in other respects, but differing considerably in their strike, have been opened up by the workings at the Hülfe-Gottes Mine at Nanzenbach. Some of these lodes have contained a sufficient amount of nickel to admit of its being extracted with advantage.[1] The nickeliferous ores contain on an average from 12 to 15 per cent. of copper and about 3 per cent. of nickel. Arsenic and cobalt are not usually present, but sometimes occur at the intersection of the lodes by cross-veins.

Ores of antimony sometimes occur in the Devonian rocks of Rhenish Prussia between Wintrop and Uentrop, four miles from Arnsberg, where a bituminous limestone, from six to eighteen inches in thickness, alternates with clay slates and siliceous shales. All of these strata, which are overlain by Millstone Grit, are occasionally penetrated by stibnite, which is usually most plentiful towards the middle of the various beds, and gradually becomes less so near their planes of separation.[2] The more massive portions of the stibnite sometimes include fragments of the enclosing rock, and the ore not unfrequently penetrates into cracks and fissures. Cervantite, antimony ochre, is found as a product of alteration near the surface, and the rock sometimes contains a little iron pyrites, blende, calcite, and fluor spar. As early as the year 1833 the Caspari Mine had opened up eleven of these metalliferous strata, near which, but without any apparent connection with them, are veins of heavy spar containing copper pyrites and ores of bismuth. At the Hoffnung antimony mine, near Brück on the Ahr, the Devonian slates strike nearly north and south with a dip of about 45° towards the west. The ores of antimony occur over a band which is sometimes as much as 120 feet in width, and which in 1827 had been opened upon, in the direction of the strike of the strata, for a distance of about 560 feet. The stibnite, which is associated with iron pyrites and brown spar, is found partly in true veins and partly between the planes of stratification, or in cleavage fissures.

Iron ores occur in the Devonian rocks of the Duchy of Nassau in the form of beds, lodes, contact deposits, segregations, and surface deposits.[3] In the neighbourhood of Dillenburg and Wetzlar,

[1] v. Koenen, *Zeitschr. d. d. geol. Gesellsch.*, 1863, vol. xv. p. 14.

[2] Buff, *Karsten's Arch.* vol. vi. 1827, p. 54, and 1833, vol. vi. p. 439. B. v. Cotta, " Die Lehre von den Erzlagerstätten," vol. ii. p. 154.

[3] F. Sandberger, " Uebers. der geol. Verh. v. Nassau," 1847, p. 27. H. Bauerman, " Metallurgy of Iron," London, 1882, p. 80. A. Nöggerath, *Zeitschr. Berg. Hütt. Salinenw.* vol. xi. 1863, pp. 63-94.

numerous beds of hæmatite occur associated with *Schalstein*, and, according to Sandberger, these deposits, which are frequently very irregular, invariably occur in connection with either diabase or *Schalstein*; being sometimes bounded by either of these rocks on one side and on the other by Cypridina slates. They contain numerous fossils, and are worked in five to six hundred small mines in the Duchy of Nassau alone. Stifft says of these deposits that they are distinguished as *Fluss-lager* when containing calc spar, and as *kieselige Lager* when quartz is present in notable proportion. The first often lie entirely in *Schalstein*; while diabase in many cases forms the hanging wall but never the foot wall. The siliceous beds are found entirely in diabase. In addition to hæmatite, limonite also occurs in this district, but generally in association with limestone.

A short distance north of Stockhausen, on the Lahn, a bed of iron ore occurs in *Schalstein*, near its point of contact with labradorite-porphyry; and south of Brilon, in Westphalia, a chain of porphyritic domes occurs in the Upper Devonian series, which are accompanied by lenticular deposits of hæmatite at their junction with the stratified rocks. Lodes of spathic iron ore, partially altered into limonite, frequently occur in this part of Germany, and often contain a greater or less amount of copper or lead ores, thus gradually passing into lodes of these metals with a veinstone composed of more or less altered siderite.

Large quantities of spathic iron ores occur in the Devonian rocks of the Siegen district, the most important deposit being that of Stahlberg near Müsen, where a nearly vertical wedge-shaped vein, enclosed in clay slate, has been worked since the year 1313. The greatest thickness of this mass is about seventy-five feet, its horizontal extension about 160 yards, and its depth, which has been proved by twelve working levels driven into the hill side, 260 yards. The entire mountain belongs to the so-called Coblenz beds of the Lower Devonian formation which predominates throughout the Siegen district. Clay slate is the prevailing rock, the most usual variety being greyish with an imperfect cleavage; but lustrous bluish-grey slates with a typical slaty structure are also met with, as are likewise brownish red slates called *Fuchs* by the miners. The last two varieties exercise an impoverishing influence upon the lode, and beds of hard grauwacke are frequently interstratified with the slates. The strike of the strata is north-east and south-west, with a dip of about 45° towards the south-east. The vein traverses the bedding with a dip of from 80° to 85° towards the south-east and maintains its maximum width for a distance of 60 yards. Well defined selvages are but rarely met with, and the country rock, which is principally clay slate, is almost always traversed for several yards from the lode by numerous strings of spathic iron ore. On the north, hard bands of grauwacke occur with beds resembling roofing slate; and, when these constitute the country rock, they cause the almost entire disappearance of iron ore. The lode splits into three leaders, varying from six to thirty-six feet in width, which, together with the interpolated wedge-shaped masses of country rock, attain a united thickness of 180 feet, proceed for a distance of 120 yards in the direction of the strike, and then continue as insignificant strings of quartz. The lode consists almost exclusively of spathic iron ore, of a yellowish-white colour, containing about 11 per cent. of manganous oxide, and which rarely changes into brown iron ore. In drusy cavities in this lode rhombohedral crystals of spathic iron ore one and a half inch in diameter are sometimes met with. These crystals have curved faces, and are always accompanied by crystals of quartz. Other ores, such as iron pyrites, copper pyrites, fahlerz, and galena, are met with at several points in the lode, and are comparatively abundant in the adjoining mine of Schwabengrube. The production of Stahlberg in one year never exceeded 36,210 tonnes, and in 1881 the yield amounted to only 2,657 tonnes of iron ore.[1]

The Carboniferous formation of the Ruhr district in Westphalia,[2] as at Essen, Bochum, Hörde, and various other localities, contains parallel deposits of ironstone closely resembling the blackband of the Scottish coal-fields. In addition to beds of compact ironstone, a nodular concretionary variety is of frequent occurrence in the shales of this formation. The ironstone deposits of the Carboniferous formation in the neighbourhood of Saarbrücken are usually more productive than those of the Ruhr, and for the most part consist of lenticular concretions of sphœrosiderite; this mineral also occurs in the lignite near Bonn.

THE BLACK FOREST.[3]—The Black Forest, which rises to an average height of about 3,000 feet above the sea level, consists chiefly of granite and gneiss, which occasionally alternate with and pass into one another. These are sometimes traversed by various eruptive rocks, such as porphyries, diabases, and

[1] *Zeitshr. Berg. Hütt. Salinenw.* vol. xi. 1863, p. 93. *Ibid.* vol. xxx. 1882, p. 164.
[2] B. v. Cotta, "Die Lehre von den Erzlagerstätten," 2nd edit. vol. ii. p. 120.
[3] Braun, *Ann. des Mines*, vol. xviii. 1843, p. 115. Selb, *Leonhard's Taschenbuch*, 1815, p. 320. B. v. Cotta, "Die Lehre von den Erzlagerstätten," 2nd ed. vol. ii. p. 171. F. Sandberger, "Untersuchungen über Erzgänge," 1882, Part 1, p. 40.

serpentines. A small area of clay slate, probably of Silurian age, appears to merge gradually into the gneiss near Todtenau, and there are some remains of Carboniferous strata near Schramberg and Offenburg, in which are found seams of anthracite. The New Red Sandstone is extensively developed in the neighbourhood of Baden Baden, where it reposes immediately upon crystalline rocks. In the southern portion of the region Bunter Sandstone sometimes occurs on the granitic heights of the Black Forest, and often covers them in the form of isolated caps. On the western declivity of the mountains, which descend rapidly towards the valley of the Rhine, is a succession of sedimentary rocks tilted into a nearly vertical position.

Veins containing ores of silver, lead, copper, nickel, cobalt, and antimony, associated with heavy spar, fluor spar, calcite, and quartz, are not of unfrequent occurrence; the majority of them are, however, too poor to admit of their being advantageously worked, and only at long intervals contain rich pockets of mineral. The lodes in this region are said to owe their origin to eruptive rocks, and especially to porphyries, which they always intersect whenever they come in contact with them. The galena found in these lodes is said to become gradually poorer in silver in proportion as the rocks traversed by the lodes are of more recent age. Important deposits of pea iron ore are found in various localities, and particularly in the neighbourhood of Kandern; there are also veins of limonite, which sometimes contain ores of manganese. Gold is found in the alluvium of the Rhine; and deposits of calamine occur at Wiesloch, in Baden.

The Kinzig Valley is chiefly composed of granite and gneiss, which, on the tops of the highest hills, are sometimes overlain by Bunter Sandstone. In this valley the crystalline rocks are frequently traversed by veins containing ores of silver, lead, copper, nickel, and cobalt, associated with heavy spar, calcite, brown spar, and quartz. These minerals occur so intermixed with one another that the lodes cannot be classified into distinct groups in accordance with the metals which they yield, and in some cases all the various ores above enumerated are found in the same vein. Notwithstanding the large number of veins in this district it has never been a continuously prosperous mining region, as the rich ores only occur in patches of limited extent at great distances apart.

The Wenzel Mine, in the Wolfach district, is said to have yielded large profits during the early part of the last century, and the Alter St. Joseph Mine, near Wittich, was, at about the same period, worked for native silver, argentite, and smaltite. The rare mineral, wittichenite, cupriferous sulphide of bismuth, also occurred in this mine. The Sophie Mine, in the same neighbourhood, was also at one period very celebrated, producing native silver, argentite, pyrargyrite, native bismuth, bismuthite, realgar, and copper nickel. Other similar lodes are known in the district, some of which have yielded ores of copper. Braun states that these lodes penetrate the Bunter Sandstone, and mentions one at the Güte-Gottes Mine which has granite as its foot wall and sandstone as its hanging wall. Among the other veins of the Kinzig Valley is the Friedrich-Christian, near Schapbach (p. 56), which produces galena, schapbachite or bismuth silver, and copper pyrites. Native silver, native copper, cuprite, and chalcocite occur at the Leopold Mine in a matrix of quartz and heavy spar. Similar lodes, although containing less ore, occur in various formations overlying the granite and gneiss, namely, in clay slates, Carboniferous sandstones, Bunter sandstones, and *Muschelkalk*, and they even extend into rocks of Jurassic age, in which heavy spar is the only veinstone.

In the southern portion of the Black Forest granite and gneiss again predominate, but they are here associated with rocks of Silurian age, which gradually pass into gneiss, while remains of the Bunter Sandstone are sometimes found upon the higher ground. The veins in the neighbourhood of Sulzburg, like those in the Kinzig Valley, yield ores of many different metals, but the most remarkable mine of this region is probably the Haus Baden and Carl, near Badenweiler. The lode in this place is sometimes as much as twelve feet in width, and may be regarded as a contact deposit between granite and Bunter Sandstone, but it is separated from the granite by a mass of porphyry some forty-five feet in thickness, which itself contains galena, heavy spar, and fluor spar. The veinstone is composed of heavy spar, fluor spar, and quartz, containing argentiferous galena, copper pyrites, and chalcocite, which near the surface have frequently become transformed into various secondary minerals.

The lodes of the Münster Valley closely resemble those in the neighbourhood of Sulzburg, while similar veins occur in the Hofsgrund, on the Erzkasten, and in the neighbourhood of Todtenau.

In the middle ages gold washing was actively carried on in the Rhine Valley between Mannheim and Basle, and v. Cotta states that, in 1859, 400 persons were occasionally employed in gold washing in the Grand Duchy of Baden. The gold is found among the sands and pebbles on the banks of the Rhine, associated chiefly with ilmenite and rose-coloured quartz, in scales never exceeding a millimetre in diameter. The entire bed of the river is auriferous, but it is in certain localities only that the sands will repay the expenses of working. The gold-washings commence below Basle, in the neighbourhood of Istein and Alt-Breisach, but the most productive localities are between Kehl and Dachslanden, especially opposite the village of Helmlingen; there are also a few washings below Philippsburg, but their yield is exceedingly small.

Calamine occurs in the *Muschelkalk*, but this deposit differs materially from those of Upper Silesia, which occur in the same formation. According to official documents, mines of argentiferous galena were worked in the range of hills between Nussloch and Wiesloch as early as the eleventh century, but mining for calamine was not commenced until the year 1851. The rock is intersected by vertical fissures, in which carbonate of zinc without any admixture of silicate occurs, accompanied by brown iron ore and galena. When the encrinal beds rest upon the compact limestone the fissures often widen out and contain very rich ore. The presence of numerous fossils converted into calamine indicates that the formation of the ore is the result of the alteration of limestone into calamine.

Extensive deposits of pisolitic iron ore are found in the Jurassic formation in the vicinity of Kandern, Stockach, Möhringen, and Jestetten, as well as more to the north in the Baier Valley. The longest worked and most important of these mining districts is that of Kandern, where the iron ore forms part of a sandy deposit varying from one to one hundred feet in thickness, and which, for the most part, overlies rocks of Jurassic age. This deposit, which is known as the *Erzgebirge*, in some places comes to the surface, or is covered by alluvial detritus, but is more frequently overlain by a Tertiary limestone conglomerate locally known as *Steingang*. In 1865 about eight mines were working in the district around Kandern and Kleingau, and iron mines are said to have been in operation in this part of Germany for more than ten centuries.

Immediately below the vegetable soil at Mösskirch is a layer of some inches of sand, beneath which are several inches of pisolitic iron ore mixed with pebbles, sand, and sharks' teeth. Below this is another layer of sand, covering the chief deposit of iron ore 3½ feet in thickness, containing boulders associated with shells, sharks' teeth, and Oolitic and Tertiary fossils. The whole is firmly cemented together by hydrated ferric oxide, while the boulders, which are principally quartz, frequently contain white mica. Flinty concretions are sometimes met with, and angular or rounded fragments of Tertiary sandstones are by no means of unfrequent occurrence.

The miners distinguish two kinds of ore; namely, *Reinerz*, pure ore, and *Bohnerz*, pisolitic ore. The first of these is a lamellar, compact, or fibrous ironstone occurring either in patches, or in nodular concretions which sometimes, although rarely, attain a diameter of two feet. They are covered by a yellowish or brownish-red incrustation, and when broken are found to be composed of concentric layers, or to be fibrous, compact, or even porous. Their interior is generally hollow, or is occupied by a kernel of clay or sand. When hollow the surfaces of the cavities are often lined by incrustations of hæmatite, by fibrous limonite, or by crystals of brown spar, spathic iron ore, or calcite; even Jurassic fossils are occasionally found enclosed in these nodules of clay ironstone. The *Bohnerz*, like the *Reinerz*, forms continuous nests or beds, but the two sometimes occur together in the same deposit. The larger nodules of *Bohnerz* vary in size from a pea to a walnut, and are always formed of concentric layers more or less firmly cemented together. Jasper likewise occurs with both varieties of ore, and is always grey when associated with *Reinerz*, but may be either grey or red when found with *Bohnerz*.

B. v. Cotta says, with regard to these deposits, that the separate members of the two varieties of ore, including the jasper, evidently belong to the Jurassic period, but were deposited in their present position during Tertiary times, as is shown by the sharks' teeth, bones, and fragments of Molasse sandstone which accompany them. He further remarks that the nodules of ore and jasper cannot be ordinary pebbles as, if so, their external form would not so exactly correspond with their internal structure.

THE PALATINATE.—Ores of mercury occur in the eastern portion of the Saarbrücken Coal-basin in lodes, as impregnations in slates, sandstones, and ironstones, and as conglomerates of Lower Permian age, as well as in the melaphyres, amygdaloids, and porphyries which have in various places burst through them. Lodes containing ores of this metal are found at the Potzberg in sandstone and argillaceous shale; at Mörsfeld in melaphyre-conglomerate, claystone-conglomerate, and claystone; at Rathsweiler, Erzweiler, and Baumholder in melaphyre and amygdaloid; and in the Königsberg and Lemberg in quartz-porphyry. These veins are sometimes accompanied by claystones and hornstones, which are otherwise unknown in the district, and may perhaps be products of the alteration of sandstones and ordinary clay slates. In claystones and hornstones the lodes are usually metalliferous, but become comparatively unproductive upon passing into other rocks. Sandstones and conglomerates have sometimes contained rich deposits of ore, but the clay slates are almost invariably barren. The only known exception to this rule is the occurrence of cinnabar in the casts of fossil fish, in the clay slate near Münsterappel, on the right bank of the Appelbach.

The lodes of this district are for the most part associated in small groups in which the principal leaders assume a certain parallelism, but both lodes and impregnations appear to be productive at short distances from the surface, only to become gradually poorer as greater depths are attained. The greatest depth reached at Potzberg, Landsberg, and Mörsfeld, was about 120 fathoms. Cinnabar is the most common ore of mercury present, and usually occurs in the form of thread-like strings, or as crystals in small drusy cavities either in the vein or in the country rock. The other mercurial substances present are native mercury, native amalgam, calomel, and, more rarely, mercurial fahlerz. Generally speaking, the lodes are principally filled with clay, but calcite, heavy spar, quartz, hornstone, chalcedony, and bitumen are also sometimes present. The associated minerals are iron pyrites, which is sometimes argentiferous, red and brown hæmatite, spathic iron ore, galena, fahlerz, copper pyrites, pyrolusite, and psilomelane. The extension in the direction of its strike is, at Landsberg, on the Gottesgabe Lode, 450 fathoms. The Mörsfeld lodes extend for a length of about 200 fathoms, but very few of the others are more than 100 fathoms in length.

Important mines of quicksilver sprang up at Obermoschel and Landsberg,[1] in the Palatinate, about the middle of the fifteenth century, and the Erzengel Mine alone is said to have afforded as much as 9,000 lbs. of quicksilver annually. In the year 1765, the Palatinate Zweibrücken mines together yielded 43,000 lbs. of quicksilver, but they have now for many years become almost completely exhausted. In the year 1879, the mines of Lemberg and Kellerberg

[1] H. v. Dechen, *Karsten's Archiv*, vol. xxii. 1848, pp. 375-464.

were re-opened, but their production has been very small; in 1879 they yielded 14·25 tonnes of ore, worth about £20; and in 1880, 29 tonnes, of the value of £35. No returns of ore were made in the year 1881.[1]

THE HARZ.—Mining in the Harz was first begun in the year 968, during the reign of Otto I., the first workings having been commenced at Rammelsberg, near Goslar. Between the years 1004 and 1006 the mine was abandoned in consequence of plague and famine, but was resumed in 1016. In the fourteenth century the workings at Rammelsberg fell in, 400 miners were killed, and in consequence mining was abandoned for about 100 years. In 1473 the Meissner Adit was begun by miners from the Meissner district, who understood working in hard rock with the gad and hammer better than the local miners, and blasting with powder was tried in the middle of the fifteenth century. In 1820 the Rammelsberg was removed from the jurisdiction of the town of Goslar and handed over to the *Communion Harz Verwaltung*, which is so divided that Hanover receives four-sevenths and Brunswick three-sevenths of the profits.

Mining was begun at Zellerfeld, Wildemann, and Clausthal, in the Upper Harz, in the year 1000. Mining flourished in the thirteenth century, but came to a standstill in the middle of the fourteenth, on account of difficulties experienced in draining the mines. At the beginning of the sixteenth century the mines were worked on an extensive scale, but were again abandoned during the Thirty Years' War. Owing to improvements which had in the meantime been made in pumping machinery, the mines were successfully re-opened at the beginning of the eighteenth century, and have continued in operation to the present day.[2]

The Harz comprehends an approximately elliptical, upland area, the greater axis of which is twice as long as the smaller, consisting for the most part of sedimentary formations of Devonian and Lower Carboniferous age.[3] Grauwacke, clay slate, siliceous slate, and quartzite are the predominating rocks, with subordinate beds of limestone. These strata are frequently broken through by igneous rocks, especially by the granite masses of the Brocken and Ramberg. Around the older rocks is a mantle of more recent formations, namely, Upper Coal-measures, Permian, Triassic, Jurassic and

[1] *Zeitschr. Berg. Hütt. Salinenw.* vol. xxviii. 1880, p. 186. *Ibid.* vol. xxix. 1881, p. 189. *Ibid.* vol. xxx. 1882, p. 187.

[2] Dr. A. Gurlt, "Bergbau und Hüttenkunde," Essen, 1879, p. 16.

[3] A. v. Groddeck, "Abriss der Geognosie des Harzes," Clausthal, 1883, p. 22.

Cretaceous rocks, which may be regarded as defining the limit of the mountain district.

The principal riches of the Harz consist in lodes and deposits of silver, lead and copper ores, sometimes united with ores of cobalt and nickel; in lodes of antimony; in segregations of pyrites; and in lodes, beds, and deposits of ores of iron and manganese. The copper schist of Mansfeld, in the Lower Harz, is very extensively worked.

The lodes producing ores of these metals occur chiefly in the Devonian and Lower Carboniferous rocks of Clausthal and Zellerfeld, in the Devonian rocks of the Rammelsberg, in the Silurian rocks of St. Andreasberg, and in slates of the same age at Harzgerode in the Eastern Harz.

A. v. Groddeck describes[1] the celebrated lodes of the North-west Upper Harz, on the plateau of Clausthal, as traversing Devonian strata and Culm-measures, and states that a displacement of the country rock to a distance of 218 yards occurs at Bockswiese and Lautenthal, where the lode fissures have Devonian strata on the foot wall and Culm-measures on the hanging wall. The lode-groups form a system of rays which spreads out from the Upper Kellwasserthal, beneath the Brocken, towards the west. In this system three main rays may be distinguished: the most southerly of which has a general strike of N. 75° W. (7 o'clock[2]), and is formed by the Silbernaaler group, the United Burgstädter and Rosenhöfer groups; and the Schulthaler group. The Lautenthal-Hahnenkleer and the Bockswiese-Festenburg-Schulenberger groups, which have a general strike N. 45° W., belong to the middle ray. The eastern ray is composed of a group which, up to the present time, has not been much investigated: its direction is N. and S. Between these main lodes, especially between the south and middle groups, several others occur, among which may be mentioned the Zellerfelder, the Herzberger, and the Hütschenthal-Spiegelthaler groups. Next to the metalliferous veins are two destitute of ore, the *faule Ruschel* and Charlotte Lode, which run nearly parallel to the strike of the beds, namely, from N. 45° to 75° E.

The lodes, which have distinct selvages on the foot wall, are split up and mixed with the country rock on the hanging wall,

[1] A. v. Groddeck, *Zeitschr. d. d. geol. Gesellsch.* vol. xviii. 1866, p. 693, and vol. xxix. 1877, p. 440. *Zeitschr. Berg. Hütt Salinenw.* vol. xxi. 1873, p. 1. B. Rösing, *Ibid.* vol. xxv. 1877, p. 280.

[2] In expressing the strike in hours we must imagine the horizon to be divided into twice 12 hours, each hour representing 15°. The direction N.S. is hour 12, midnight and midday; E.W. is hour 6, morning and evening.

and sometimes reach a thickness of more than 20 fathoms; their dip is at a great angle towards the south and south-west, rarely towards the north or east. The filling of the lodes principally consists of country rock, grauwacke, and clay slate in a more or less altered state, together with lustrous black slate. Between these fragments of country rock, the gangue and ores lie in the form of strings and impregnations; brecciated lodes are very general. The gangue is quartz, spathic iron ore, calc spar, and heavy spar; the principal ores being argentiferous galena, blende, and copper pyrites. These ores are very unevenly distributed in the lode cavities, and numerous veins are characterised by the predominance of a quartzose gangue, with galena, as in the case of the Zellerfeld lodes; others, such as the Burgstädter lodes, are filled with quartz, calcite, galena, and blende. In some places copper pyrites occurs, as at the Charlotte Mine, or zinc blende, as at Lautenthal, where it is the principal ore. In an exhaustive memoir recently published, F. Schell[1] describes the lodes of the North-western Upper Harz as having a general strike from south-east to north-west. Formerly they were represented as being parallel, and this to a certain extent is true, although it can no longer be considered as strictly correct. The whole system of lodes should rather be regarded as a network, because they are almost all connected either by intersecting veins or by flucans. The majority of the lodes dip to the south-west, and on this account have been termed "right dipping," in contradistinction to those inclined in the opposite direction, which are styled "reverse dipping." The latter occur chiefly in the Rosenhöfer lode-group. In describing the lodes according to their character and constitution, it is desirable to employ the expression *Gangzug*, lode-group, because it signifies to a certain extent that they were formed at one time, or may even be at present in course of formation.

Commencing in the south and ending in the north, these lode-systems are the following:—

1. The Laubhütter-Adit lode-group.
2. The Hülfe-Gotteser and Isaakstanner lode-group.
3. The Silbernaaler lode-group.
4. The Rosenhöfer lode-group.
5. The Burgstädter lode-group, and the Zellerfelder main lode-group.

[1] "Der Bergbau am nordwestlichen Oberharze," *Zeitschr. Berg. Hütt. Salinenw.* vol. xxx. 1882, p. 83.

6. The Haus-Herzberger, Spiegelthaler and Spätenthaler lode-group.
7. The Schulenberger and Bockswieser lode-group.
8. The Hahnenkleer and Lautenthaler lode-group.

The Rosenhöfer group has the most complicated network of lodes of any in the North-western Upper Harz. Forming part of it is a perfect entanglement of veins, completely shut in by two main lodes, namely, by the hanging wall of the Thurmhöfer and foot-wall of the Liegender-Altensegener Lode. Between these the most varied fissures occur, containing more or less ore. There are also several diagonal lodes which render the mapping of this network still more difficult, namely, the Ziller foot vein and hanging vein and the Braunlilier Vein. Within the network are several reverse-dipping veins, and lastly there is the *faule Ruschel* coming from the Burgstädter Hauptzug which joins the Altensegener Lode.

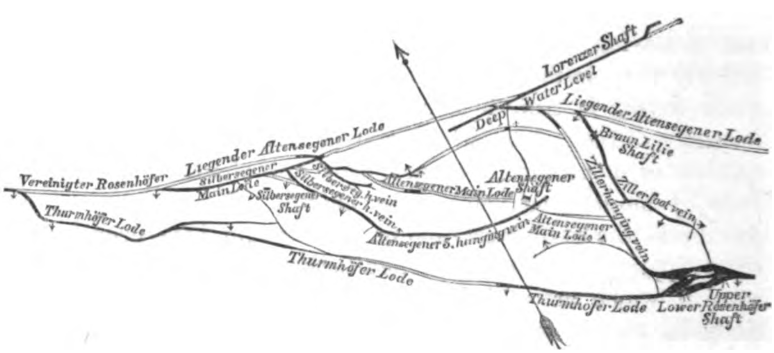

FIG. 62.—Rosenhöfer lode-group; horizontal section.

Fig. 62, which is a horizontal section of the group along the water-level, will not only serve to give an idea of the position of the various branches but also furnishes an example of the general mode of occurrence of mineral veins in the Upper Harz. From the drawing it will be seen that near the south-eastern shafts of the Rosenhöfer group, as well as somewhat further east and west, the lode fissure has widened considerably through the union of several veins. The Thurmhöfer Lode emanates from its hanging wall, while the foot-wall of the Altensegener Lode is connected by two diagonal cross-courses with the main fissure.

The contents of the Rosenhöfer Lode consist of spathose iron ore, in addition to argentiferous galena, and on this account its ores are easily fusible. Beautiful specimens of fahlerz are met with in the Silbersegener shaft, while fine crystals of galena occur in some of the others. The ores are associated with clay slate, grauwacke, and heavy spar. Deep down, but only in the Rosenhöfer Mine, blende is found accompanying lead ores; but this does not occur in the upper part of the lode.

The most important of the Clausthal veins occurs in the Burgstädter group, and seldom has any lode been richer in massive lead ores. The occurrence of solid galena is specially to be noted at two points, namely, in the Dorothee Mine and in the Herzog Georg-Wilhelm Shaft.

Fig. 63 represents the Burgstädter lode-group, from which it will be seen that it is not a single vein, but is associated with several others, although no distinct network is present as in the

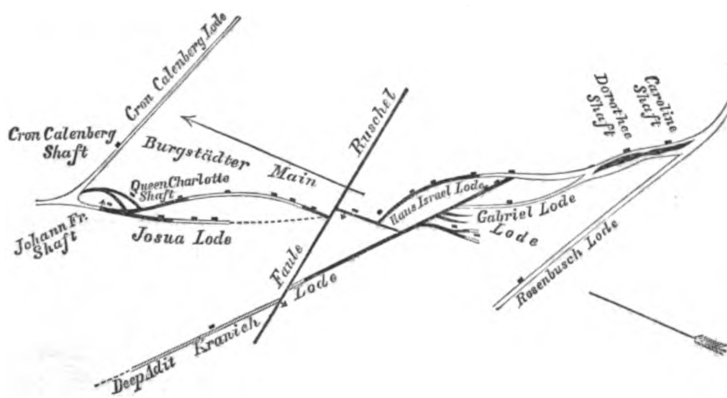

FIG. 63.—Burgstädter lode-group; horizontal section.

Rosenhöfer ground. At the north-western end of the Burgstädter Lode, the Cron-Calenberger Lode occurs, and at this point also originates the Zellerfelder main-lode with its variable branch veins. It may be assumed that the Cron-Calenberger Vein has essentially been filled by infiltrations from the Zellerfelder lode fissure, and that the galena in the vicinity of the Ring Shaft has originated from this lode. The Ernst-August Mine is at present the most westerly on this course, and in this extended lode the contents vary considerably, the galena being accompanied by clay slate, grauwacke, calc spar, quartz, a little spathose iron ore, copper and iron pyrites, and, deeper down, by blende. It is noteworthy that the ore in the eastern portion is associated with clay slate and grauwacke; in that to the west of this compact calc spar occurs, while still further west the lode becomes more quartzose; the Gabriel Lode being specially rich in quartz. Although galena is the ore chiefly raised, yet in the Königin Charlotte Mine the ore is not galena but copper pyrites.

In the Zellerfeld mines the quartzose character of the lode is still more marked. There is, however, another circumstance to be noted which is very characteristic of the Ring and Silberschnurr Mine. Here the galena, in certain parts of the lode, occurs in annular and polygonal forms which enclose parts of the gangue and country rock. The whole face of the lode is often covered, as it were, with different figures, and the enclosed fragments of rock are all of the same kind, although they often differ in colour, structure, and density. As these figures usually approximate to rings, it may be assumed that the mine has acquired its name from this circumstance.

In the Schulenberger and Bockswieser group, ore is found in two zones only, which are tolerably distant from one another, namely, to the east near Schulenberg and Festenburg, and to the west near Bockswiese.

The following remarks apply not only to these lodes but to all those of the Upper Harz generally:—

If the contents of a lode are soft and easily weathered, a depression commonly results along its outcrop, as in the Charlotte Lode near Wildemann. Sometimes, however, clay is formed by the weathering of the veinstone, and this, being impervious, gives rise to a swamp. If the contents of a lode are quartzose and less easily disintegrated than the country rock, then the weathering causes the lode to project from the surface of the ground like a wall. This may be well seen at different spots on the Schulenberger and Bockswieser group. Here the lode presents another peculiarity, which is characteristic of the Herzog, August, and Johann-Friedrich Mines, namely that the veinstone of the western part of the lode is essentially softer than that of the eastern portion.

The celebrated mining district of St. Andreasberg[1] is situated on the southern edges of the Rehberg and Sonnenberg, on the south-west end of the Brocken mass of granite; the lodes being enclosed in a narrow zone of Silurian clay slate and grauwacke, bounded on the north by granite and on the south by diabase. The lodes are in some cases destitute of ore, while in others they contain ores of silver, iron, or copper. The barren

[1] H. Credner, *Zeit. d. d. geol. Gesellsch.*, vol. xvii. 1865, p. 163. B. v. Cotta, "Die Lehre von den Erzlagerstätten," 2nd ed. vol. ii. p. 90.

veins often attain a width of above 180 feet, and are filled by fragments of clay slate and clay; they dip from 55° to 75° towards the south, and extend a great distance on the line of strike. Two of these barren veins, the Neufanger towards the north, and the Edelleuter towards the south, enclose a horse or long ellipsoidal mass of rock, consisting principally of clay slate, above 2,500 fathoms in length, and more than 500 fathoms in width. On one side of this large enclosure of country rock is the Edelleuter vein, or flucan, which continues in nearly a straight line, while the Neufanger vein forms an arch on the other. Within this space only are silver lodes ever found, and they do not extend beyond the enclosing veins. All the lodes known at St. Andreasberg outside this space contain, with but few exceptions, only iron ores and copper pyrites.

Two systems of silver lodes are distinguished according to their direction. The first is composed of several lodes which strike N. 22° to 37° W., and dip at a great angle towards the north-east. The most important of these are the Franz-August Lode, the Samson Lode, and the Jacobsglück Lode. Two lodes only belong to the second system, namely the Gnade-Gottes and the Bergmannstrost Lodes, which strike nearly parallel to the limiting flucan, and dip 60° to 85° north. The silver veins are not very large, few of them being above eighteen inches in width. The principal gangue is calc spar, and the most important ores are galena, antimonial and arsenical silver ores, and native arsenic; these are accompanied by apophyllite, harmotome, desmine, stilbite, and fluor spar. The silver lodes cross and frequently dislocate one another, but calcite is always the most abundant gangue. The iron lodes outside the enclosed ellipsoid of country rock are filled with compact red iron ore, and with several veins of copper pyrites and cobalt ores, from a zone parallel to the edge of the granite.

The presence of zeolites, the comparative scarcity of galena, and the predominance of rich silver ores, characterise the St. Andreasberg lodes and distinguish them from those of Clausthal, in which galena is abundant and the other minerals do not occur. Some of these lodes have a very regularly banded or combed structure, and it would appear that their origin is in some way intimately connected with the intrusion of the neighbouring diabase. Many of the minerals present, such, for instance, as cerargyrite, tinder ore, and ganomatite, are evidently products of the decomposition of other substances. The Samson Lode has been worked and found to be productive to a depth of 2,590 feet, although on account of the limited extent of the ore ground it has been followed horizontally for a distance of about 2,100 feet only.

In the district of Harzgerode and Neudorf,[1] which is of considerable interest to the mineralogist, the lodes are principally enclosed in clay slates of Silurian age. This is especially the case in the Meisenberg and Pfaffenberg, where their strike is south-east and north-west parallel to the principal axis of the Harz. The veinstone consists of quartz, spathic iron ore, and calcite, with which are associated galena, iron and copper pyrites, tetrahedrite, bournonite, stibnite, and occasionally traces of wolfram. These lodes also frequently contain fragments of country rock, which are often surrounded by concentric layers of different ores in the following order, namely, spathic iron ore, quartz, finely granular galena, dark brown blende, coarsely granular galena. Zinken has described some of the mineralogical peculiarities of these veins, particularly those belonging to the Birnbaum group, and has pointed out that in some places the fissures, instead of having become filled with ordinary veinstone, contain only clay slate traversed by numerous small branches. In the clay slate these small veins consist of quartz, but when the wall rock is composed of porphyry they are filled principally with galena. In the year 1879 Neudorf produced 1,414 tonnes of lead ore of the value of £7,417.

The Rammelsberg[2] is a mountain on the northern borders of the Harz, nearly two English miles south of the town of Goslar, of which the summit is 2,076 feet above the sea level. The rock consists of three members of the Devonian formation, namely, the Goslar slate, formerly called Wissenbach slate by F. A. Römer, the Calceola slate, and the Spirifer sandstone. These rocks lie above one another in reversed order, so that the Spirifer sandstone forms the summit of the mountain; beneath this comes the Calceola slate, and lastly the Goslar slate. The characteristic cleavage of the Goslar slate is not usually met with at the Rammelsberg, as the cleavage and stratification coincide; the interstratified limestone and quartzite being parallel with the strata containing fossils. When the plane of stratification of the slate has a dip greater or less than 45°, traces of

[1] Credner, "Geogn. Verhaltn. Thuring. u. d. Harz," 1843, p. 123. Zinken, *Leonhard's Jahrbuch*, 1850, p. 692. B. v. Cotta, "Die Lehre von der Erzlagerstätten," vol. ii. p. 89.
[2] F. Wimmer, *Zeitschr. Berg. Hütt. Salinenw.* vol. xxv. 1877, p. 119.

cleavage may be again remarked, particularly to the north-west of the Winterthal.

The Rammelsberg ore deposit consists of an aggregation of irregular lenticular masses of ore of varying dimensions, its greatest extension in the direction of the strike being 655 fathoms, and its usual thickness from 45 to 60 feet, which sometimes, where the ore mass separates into two branches, extends to above ninety feet. Like the country rock it has a strike towards east-north-east and west-south-west, with a dip 45° south-east following all its contortions. The Rammelsberg ore deposit is consequently a true bed, and an independent member of the Goslar slates.

Fig. 64, representing a transverse section across the Rammelsberg, and Fig. 65, a section on a larger scale across the ore bed, will serve to show the mode of occurrence of the ores in this mine.

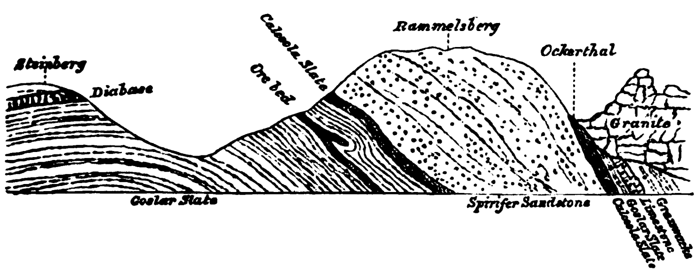

FIG. 64.—Section across the Rammelsberg.

This deposit was regarded by Delius (1770) as a stockwork, and was described by Lasius (1789) as being neither lode, stock, nor stockwork, but as a "rhomboidal parallelopipedon of ore." Böhmer (1793) called it an *Erzflötz* or ore seam, and the branch he considered a true lode. Reichetzer (1821) calls it a *stehender Stock;* B. v. Cotta calls it a *liegender Stock*, or recumbent segregation, while Gatterer and Hausmann regarded it as a bed.

This bed is composed of lenticular aggregations of pyrites, which consist of compact masses of

1. Galena with blende and iron pyrites.
2. Galena with heavy spar.
3. Copper and iron pyrites.

The minerals of the Rammelsberg ore bed may be divided into three classes:[1]—

[1] F. Ulrich, "Die Mineralvorkommnisse in der Umgegend von Goslar," 1860.

a. Minerals which originally formed the bed.

b. Minerals which occur in fissures and veins in the ore-mass.

c. Minerals which have been formed by the decomposition of the two preceding.

a.—Of this class the prevailing constituent is iron pyrites. Copper pyrites, always mixed with iron pyrites, and sometimes with fahlerz is also present. Galena occurs in a compact form, but when mixed with pyrites it constitutes the so-called *melirten Erze;* when in association with blende, iron pyrites, and heavy spar, it forms lead ore proper, which is called "brown ore" or "grey ore," according

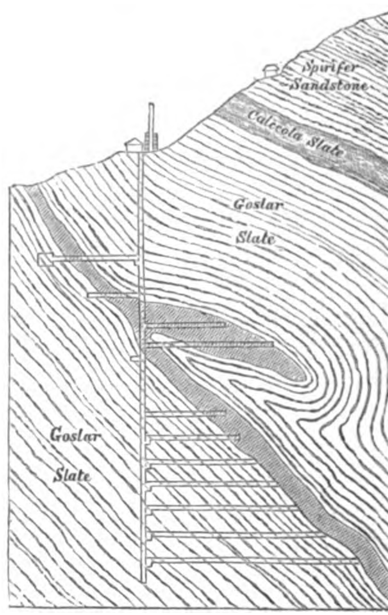

FIG. 65.—Section across the ore bed, Rammelsberg.

as blende or heavy spar predominates. Blende occurs in compact masses, as does also heavy spar; quartz is exceedingly rare.

b.—In class *b*, copper pyrites is found in beautiful crystals, crystallised fahlerz and galena also occur; while the blende is usually compact. The heavy spar is crystallized, and filling the fissures are found calcite, calamine, gypsum, spathic iron ore, and quartz.

c.—A number of interesting secondary minerals are being formed in the ancient workings of the Rammelsberg Mine by the decomposition of the original ores. Among these sulphate of iron, rarely crystallized but often in a stalactitic form, is of frequent occurrence, as are also botryogen, rœmerite, voltaite, copiapite, and vitriol ochre. Sulphates of copper, zinc, and calcium, are also present, as is also *hair-salt*, a magnesian aluminium sulphate containing sulphates of zinc and iron.

Professor G. Köhler[1] of Clausthal has brought forward additional evidence of the correctness of the view that the Rammelsberg deposit is a true ore bed, and an independent member of the Goslar-slate series, and in his paper on this subject gives drawings of a number of specimens of the ores, showing that all the contortions of the surrounding rocks are shared by the ore bed itself.

According to official returns the production of the principal mines of the Harz, during the year 1881, was as follows:[2]—

Mines.	Lead Ores.		Copper Ores.		Zinc Ores.	
	Weight.	Value.	Weight.	Value.	Weight.	Value.
	Tonnes	£	Tonnes.	£	Tonnes.	£
Clausthal . . .	10,147	200,752	424	1,752	493	16,435
Lautenthal . .	1,758				5,238	
Silbernaal . . .	4,146					
St. Andreasberg	109					
Rammelsberg .	27,547	11,143	19,365	28,087		
Totals . . .	43,707	211,895	19,789	29,839	5,731	16,435

In addition to the above Andreasberg produced, during the year 1881, 122 tonnes of silver ore of the value of £5,901.

Inclusive of cupriferous lead ores and iron pyrites, the production of Rammelsberg in 1881 amounted to 46,990 tonnes.

Mining was commenced in the county of Mansfeld,[3] on the southern declivity of the Harz, in the year 1199, and has, with but little interruption, continued flourishing up to the present time. In the fifteenth century about 1,000 tonnes of copper were annually produced, but, during the sixteenth, mining was for some

[1] "Die Störungen im Rammelsberger Erzlager bei Goslar," *Zeitschr. Berg. Hütt. Salinenw.*, vol. xxx. 1882, pp. 31 and 278.

[2] *Ibid.* vol. xxx. 1882, pp. 175, 186. *Ibid.* vol. xvii. 1869, p. 259. *Ibid.* vol. xix. 1871, p. 224.

[3] "Der Kupferschieferbergbau und der Hüttenbetrieb zur Verarbeitung der gewonnen Minern," 1881.

time interrupted by the Thirty Years' War. Working was, however, resumed in 1573 by the Elector of Saxony, since which time operations were continuously carried on by independent companies. In 1852 these companies were all consolidated into the "Mansfelder Kupferschieferbauende Gewerkschaft" (Company for working the Mansfeld Copper Schist), which now produces annually about 11,000 tonnes of copper, together with 60 tonnes of silver, and affords employment to nearly 11,000 miners.

The geological constitution of the copper-mining district of Mansfeld is, on account of the regularity of the stratification, exceedingly simple, and, with the exception of melaphyre, which occurs sparingly in the Wipper Valley and a few adjacent localities, the whole region is composed entirely of stratified rocks, of which the *Rothliegendes* forms the lowest member.

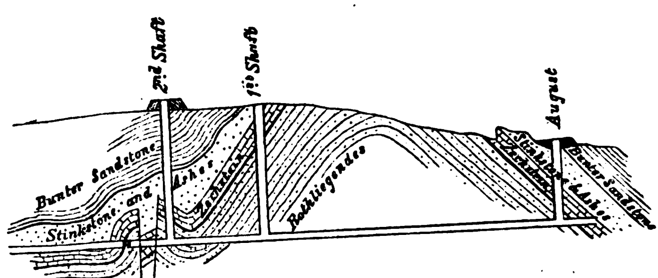

FIG. 66.—Section of the strata, Tiefthal.

Fig. 66, representing an anticlinal in the Tiefthal district, will convey a correct idea of the position of the various strata.

The *Rothliegendes,* the name applied by the miners to the sandstones and conglomerates forming the base of the Mansfeld *Kupferschiefer,* or copper schist, sometimes exceeds 500 fathoms in thickness, and exhibits many characteristic peculiarities by means of which it is easily recognised. This formation may be divided into three zones, the lower, the middle, and the upper. The lower of these divisions is characterised by a conglomerate of waterworn hornstone pebbles; the second by various beds of carbonate of lime; and the third by a sharp angular grit much employed as a material for millstones.

The *Weissliegendes* may be considered as the uppermost bed of the *Rothliegendes*, for, although this stratum, four feet six inches in thickness, resembles to some extent the layer above, particularly in its greyish-white colour, in the presence of carbonate of lime, and in its containing in its upper beds ores of the same metals as the limestone formation above, it still retains the peculiar sandstone character possessed by the *Rothliegendes.*

As a rule, the *Weissliegendes* lies on the upper clayey beds of the *Rothliegendes* as a greyish-white bed rich in mica and lime. Above this follow beds of sandstone, which possess a cementing material of a greyish-white colour rich in lime, together with, in places, beds of conglomerate containing fragments of quartz and siliceous slate. The upper bed of this sharply divided division becomes, through the disappearance of lime as a cementing material, very rich in quartz, and in places takes the appearance of hornstone.

The *Zechstein* formation at Mansfeld consists of two principal divisions, an upper and a lower. Of these the lower comprehends the *Kupferschieferflötz*, or cupriferous seam; the *Dach*, or roof, and the *Zechstein* proper; while the upper consists of the *Rauchwacke, Rauhstein, Stinkstein*, and *Asche* with gypsum and various clays.

The bituminous marl constituting the copper schist, or copper shale, lies everywhere, with the greatest regularity, on the *Rothliegendes*, so that it can be followed as a thin black band; indeed in some places, such as at the southern edge of the Harz, it even stretches beyond, which appears the more remarkable when its small thickness, only about nineteen inches, is taken into consideration. The bituminous contents of the copper-bearing bed, which, however, diminish near the top, are more characteristic than even its metallic contents, as bitumen is often present when copper ore is absent, or occurs only in quantities too small to pay the expenses of smelting.

Even on a cursory examination, without taking into consideration the greater or less proportion of copper present, the copper schist is readily divisible into several distinct layers. The deposit is most complete in all its members in the Hettstedt and Gerbstedt districts; but this is less the case in the districts of Eisleben and Sangerhausen.

The different layers of the copper schist receive from the miners the following names, and occur in the following order, beginning at the bottom.

Hettstedt, Gerbstedt.	Eisleben.	Sangerhausen.
9. Oberberge. 8. Noberge. 7. Lochberge.	Dachberge Noberge Kopf { Ober / Unter	Noberge. Unterwand.
6. Kammschale. 5. Kopfschale. 4. Schieferkopf { Ober / Unter	Kammschale. Grobe Lette.	Schieferkopf. Blattschiefer.
3. Lochschale. 2. Lochen. 1. Liegende Schale.	Feine (Loch) Lette. Wanting.	Schramschiefer. Erzschiefer.

The first division consists of the *Liegende Schale*, which is not everywhere present, after which comes the *Lochen*, consisting of a soft clayey bed, which generally lies on, and is firmly attached to, the layer of shale below; whilst above it is the *Lochschale*, chiefly distinguished by its extremely fine lamination. The entire lower division is at the most from 2 to 2¼ inches in thickness.

The second division is much coarser than the first. The *Schieferkopf*, which is divided into lower and upper, has a solid homogeneous appearance, which, however, it loses in the *Oberkopf*, which is coarser and shows an uneven fracture. This is followed by a thin layer, the *Kopfschale*, which sometimes contains strings of gypsum, though by no means with the same regularity as is seen in the next layer, the *Kammschale*.

The *Kammschale* presents a very characteristic appearance, and is everywhere readily recognisable. It is traversed by fine regular threads of gypsum, which gives it an appearance well described by the miners as "white-haired." The entire second division (4, 5, and 6) reaches a thickness of only four inches.

Much coarser, but still almost always with a distinct cleavage, is the *Lochberge*. The cross fracture is perceptibly greyer and paler than is that of the preceding layers. The *Lochberge*, being separated from the strata both above and below by smooth schistose surfaces, separates in a layer 2½ to 4 inches in thickness, and is often used as a building stone.

The *Noberge* is a still finer schist, of less clearly defined texture, in which bitumen is less readily discerned.

The *Oberberge* is grey, and already exhibits characteristics very similar to those of the layer above known as the *Dach;* the *Noberge* and *Oberberge* together attain a thickness of from 6 to 8 inches.

The lower portion of the series is, in the Eisleben district, always known as the *Lette*, and in that of Sangerhausen the layers of the lower division are usually soft, plastic, and greasy; when firmer they often contain visible grains of pitch. The *Erzschiefer*, so called on account of its greater metallic contents, is not everywhere present, and when present does not exceed a thickness of $\frac{1}{8}$ inch.

The *Dach* exhibits a coarse fracture and is not readily fissile, being usually a greyish-white compact bed of marly limestone from 6 to 14 inches in thickness, which on exposure to the air becomes yellowish-brown, and, on weathering, separates into polygonal fragments.

The *Faüle*, from 2 feet 6 inches to 3 feet in thickness, is a dark-blue solid limestone which is always distinctly marly.

The *Zechstein* proper is a dense yellowish or smoke-grey limestone with a conchoidal fracture, and is the most regular and continuous of all the strata accompanying the *Kupferschiefer* seam. It is in a high degree suitable for building purposes, since it not only occurs in regular beds, varying from 4 to 12 inches in thickness, but is also readily divided into parallelopipedal blocks. Flat lenticular bodies enclosing a dark carbonaceous mass as a kernel, probably the remains of some organism, are peculiar to the *Zechstein*. The upper layers, from 6 to 12 inches thick, are porous, the pores being of a yellow colour. This bed passes into the next of the series known as the *Rauchwacke*, which, in some districts often of considerable thickness, is in the Mansfeld district only from 18 inches to 6 feet thick, and lies on the top of the *Zechstein;* but it is seldom of great extent, thinning out and disappearing and then again appearing. It passes from a firm dark-greyish black dolomitic limestone to a yellowish-grey or yellow magnesian marl.

The *Rauchwacke* is often traversed by small fissures filled with calcite, which imparts to the rock the appearance of a breccia of which that mineral is the cementing material.

The *Asche*, which consists of a grey earthy or sandy dolomitic marl, is never absent from the top of the *Zechstein*, but is extremely variable in thickness, and is often much intermixed with other beds.

The *Rauhstein*, which is never absent where the *Asche* is present in considerable quantity, forms an intermediate link between the *Rauchwacke* and *Asche*. It is blackish-grey in colour, and resembles the *Rauchwacke* in its porous structure and the irregular arrangement of its constituents. It is usually found imbedded in the *Asche*. *Stinkstein*, from its frequent passage into the *Asche*, with which it intermingles as frequently as does the *Rauhstein*, is closely allied with these two beds. It is of a dark-grey colour and thinly fissile, the planes of division, however, being in very varying directions, owing to movements having taken place in the beds which appear to have broken the stratum and thus disturbed the foliation. The peculiar odour of the *Stinkstein* is shared to some extent by the upper layers of the whole series.

The blue clay, which forms the topmost layer of the formation, is often interstratified with red clay, and encloses layers of *Stinkstein* and *Rauhstein*. The blue clay passes into *Asche*, becoming more sandy in so doing.

Gypsum and anhydrite play an important part in the Zechstein formation penetrating all the layers down to the *Weissliegendes*, and varying from scarcely visible traces to distinct beds of greater or less thickness; almost everywhere where deposits of this mineral are bored through, anhydrite is found somewhere in the mass.

The metalliferous contents of the *Kupferschiefer* seam occur as a rule in the form of *Speise*, that is, sprinkled in the condition of very fine dust which, on a transverse fracture, causes a metallic reflection in sunlight. It has either a golden colour, from the presence of copper pyrites in predominant quantity, or a violet, blue, and copper-red colour from the presence of erubescite; more rarely the colour is steel-grey, from copper glance, or greyish-yellow from iron pyrites, and, finally, sometimes bluish-grey, from the presence of galena. Although the *Speise* principally consists of sulphuretted ores of copper, there also occur, in greater or less quantities not visible to the eye, sulphide of silver, blende, galena, iron and copper pyrites, copper-nickel and arsenide of cobalt, as well as compounds of manganese, molybdenum, and selenium; oxidized compounds and salts also occur as secondary products. In addition to the *Speise* small bands and filaments of the same ores likewise occur, filling fissures parallel to the bedding; the presence of these is not, however, sufficient to make the ore profitable for smelting when *Speise* is absent. None of the layers of the *Kupferschiefer* seam are barren of metal, but it is only in a few of the bands that it occurs in workable quantities, these being invariably the lower layers up to the *Kammschale*, which is, as a rule, the limit of smeltable ore.

At Eisleben the *Lette*, together with the *Kammschale*, are, as a rule, the productive beds, and with these is associated the *Schieferkopf*, especially on the ridges and in the hollows of the seam. In proportion as the depth increases, however, the clay or the *Kammschale* frequently becomes too poor for smelting. In the Hettstedt district the productive slate is confined mainly to the *Lochen* and *Unterkopf*, the *Oberkopf* being mostly unproductive, while *Dachberge*, worth smelting, occurs but rarely.

The term *Flötz*, seam, is usually applied to the productive bed only, the thickness of which varies from 2½ to 5 inches. With this restricted height it is of course necessary to remove a portion of the country in order to allow room for working. As the floor is hard the roof is removed to such an extent as to allow the hewer to work in a reclining position, and as the miner reclines on his side the breadth of the shoulders is the minimum height of the working space necessary. The most suitable height is about twenty-two inches, but the cupriferous band is often worked with a height of from sixteen to eighteen inches only.

In some places there occurs below the *Kupferschiefer*, on the upper part of the *Weissliegendes*, a deposit known as *Sanderze*, which usually appears as what is locally known as *gelbe Tresse*, consisting of consolidated grains of copper pyrites mixed with sand. Wherever this *Tresse* appears, it assumes the form of a golden yellow band of from one-third of an inch to one inch. The *Kupferschiefer* of the Mansfeld district contains on an average from two to three per cent. of copper with about ten pounds of silver to the tonne of copper, whilst the *Sanderze* of the Sangerhausen district reaches as high as five per cent. of copper when the ore is pyrites, to ten per cent when it consists of erubescite, the silver in this case reaching only five pounds per tonne of copper. In the northern portion of the district the schists are poorer for copper, yielding scarcely one and a half per cent.

The following analyses give the composition of copper schist during the second quarter of 1879:—

	Otto Shaft.	Ernst Shaft.	Glückhilf Shaft.
Silica	38·42	33·15	29·22
Alumina	15·93	12·90	11·76
Lime	10·93	14·39	12·66
Magnesia	3·53	2·32	2·25
Carbonic acid	7·02	10·47	9·43
Iron	1·81	3·31	2·97
Copper	2·01	2·90	2·88
Silver	·015	·016	·021
Sulphur	3·18	2·15	4·97
Bitumen by loss	14·63	9·89	17·21

Zinc, lead, manganese, nickel, and cobalt were not quantitively estimated.

As shown in Fig. 66, the *Kupferschiefer* deposit is overlain by the well-known Bunter Sandstone, which, in this district, consists of red slaty clays, red-coloured sandstones and sandy shales, oolitic beds and thick masses of gypsum. Copper schist is also worked in Hesse, and at Saalfeld in Thuringia. Some idea of the importance of the Mansfeld metalliferous deposits may be gathered from the following facts. The total number of men employed at the end of 1881 in all departments, mining, transport, smelting, &c., was 13,087, and, taking their families into consideration, the total number of persons dependent on the working of the *Kupferschiefer* was a trifle over 35,000.

In the Mansfeld district the following quantities of copper schist have been raised since 1862:—

Year.	Tonnes.
1862	61,971
1865	91,028
1868	135,284
1871	170,580
1874	192,847
1877	269,482
1878	299,601
1879	320,320
1880	394,650
1881	436,048

Besides this the Sangerhausen district, belonging to the Mansfeld Company, produced 138,405 tonnes of copper schist during the period from 1862 to 1880 inclusive; or an average of 7,284 tonnes per annum.

Sangerhausen alone, in 1880, produced 10,933 tonnes.
" " 1881 " 9,367 " [1]

Altogether, Sangerhausen and Mansfeld, in 1880, produced 405,583 tonnes, representing a value of £537,390; and in 1881, 445,415 tonnes, worth £660,487. In the year 1881 the quantity of silver and copper obtained [2] was as follows:—

Copper	10,999 tonnes.
Silver	59,836 kilogr.

[1] *Zeitschr. Berg. Hütt. Salinenw.*, vol. xxx. 1882, p. 183.
[2] *Ibid.* vol. xxx. 1882, p. 226.

The iron ores of the Harz,[1] which are very widely distributed, chiefly consist of hæmatites and limonites, although both magnetite and spathic iron ore are also occasionally met with. B. v. Cotta remarks that the comparative rarity of magnetite may probably be explained by the absence of crystalline schists, since it is principally in such rocks that deposits of iron ores have become changed into magnetite by the metamorphic action which has caused the alteration of the rocks themselves. In the Harz, as in numerous other localities, iron ores are for the most part associated with igneous rocks, either being enclosed within them, or forming contact deposits in their immediate vicinity. They occur usually, but not universally, in connection with diabase, and are found in the form of beds, veins, and irregular deposits.

Many of the masses of greenstone penetrating the Silurian rocks of the Eastern Harz, near Tilkerode, contain deposits of hæmatite, which, according to Zinken, do not extend into the surrounding clay slates. They occur either as irregular lodes in the diabase, or form deposits between it and the neighbouring slate, and it is remarkable that, in addition to iron ores, they sometimes contain various compounds of selenium, such as clausthalite, lehrbachite, and tilkerodite associated with auriferous palladium. As is usually the case, when spathic iron ore is present it has, near the surface, been converted into limonite. Similar deposits occur at Elbingerode, Lehrbach, and Zorge; while on the Krokenstein, near Hüttenrode, hæmatite forms a contact deposit between limestone and clay slate. Little appears to have been done during the last year either at Tilkerode or at Zorge, while at Lehrbach three men only were employed. During the year 1881 Elbingerode produced 4,600 tonnes of brown iron ore and 2,173 tonnes of red hæmatite.

The manganese deposits of the Harz are almost exclusively confined to the neighbourhood of Ilfeld, where they occur in porphyrite in the form of veins varying from a few inches to nearly two feet in width, and of which the usual strike is between N. 82° W. and N. 30° W. The ores, which are in part compact and in part crystallized, consist of manganite, pyrolusite, varvicite, braunite, hausmannite, psilomelane, and wad; the associated matrix consisting of calc spar, heavy spar, brown spar, and, sometimes, carbonate of manganese, with crystals of clac spar coloured black by manganic oxide. These lodes are invariably accompanied by branches in

[1] Zinken, "Der östliche Harz," vol. i. 1825, p. 135; Credner, "Geogn. Verh. Thür. u. des Harzes," 1843, p. 127; Kerl, *Berg. und Hüttenm. Zeit.* 1853, p. 148.

which ores of manganese occur in a compact form and without any admixture of matrix. They are seldom productive to a greater depth than about six fathoms, although in a few exceptional cases they have been followed to beyond thirty fathoms. The porphyrite of Ilfeld is in some places traversed by lodes of iron ore.

During the year 1881 the Ilfeld mines produced 144 tonnes of manganese ore of the aggregate value of £1,315.[1]

THE THURINGIAN FOREST.[2]—Iron ore was at a very early period worked in the Thuringian Forest, iron works having been built near Saalfeld in 1071. Gold was mined at Goldisthal in prehistoric times, while the gold-washings and gold mines at Reichmannsdorf and Steinhaide, near Saalfeld, were flourishing in 1209; they were, however, abandoned in 1430, but resumed in 1533. The Güte-Gottes Mine at the Petersberg, from 1576 to 1580, yielded about seventy-five pounds of fine gold. It was abandoned in 1635 on account of the Thirty Years' War, but in 1692 was resumed by foreign miners procured by Duke Albrecht. In the year 1700 there were gold-washings on the Werra and the Ilz near Schwarzenbrunn and Schalkau, but they do not appear to have been successful. The only ores at present obtained in this region are those of iron and manganese, with a little antimony and a still smaller quantity of copper ore.

Geologically, the Thuringian forest is divided into two portions of very unequal areas. The south-eastern part, which joins the plateau of the Fichtelgebirge, and from which it is separated by no natural boundary, consists, principally, of Silurian rocks bounded on the north by Permian strata, and on the south-west by rocks of Carboniferous, Permian, and Triassic age. This district is penetrated by but few masses and dykes of granite or other eruptive rocks, and is by no means rich in metalliferous veins. The north-western portion consists of a small mountain ridge, of which the geological characteristics are much varied. Here granite, syenite, gneiss, and mica schists appear to be the oldest rocks and are frequently traversed by various porphyries and greenstones. In the Silurian rocks of the south-eastern district considerable quantities of hæmatite and limonite are mined, particularly in the neighbourhood of Steinach and at Schmiedefeld, near Gräfenthal, where a bed of iron ore courses parallel to the strike of the enclosing slates.

[1] *Zeitschr. Berg. Hütt. Salinenw.* vol. xxx. 1882, p. 188.
[2] Krug von Nidda, *Karsten's Archiv.* vol. xi. 1838, p. 13. Credner, "Geogn. Verhält. Thüring. u. d. Harz," 1843, p. 130.

At Weitisberga, near Lehesten, in the vicinity of a mass of intrusive granite, are several lodes which appear to occur in small masses of greenstone which penetrate the slates, but are not found in the slates themselves. These veins contain small quantities of galena, blende, and copper pyrites, intimately intermingled with a gangue consisting, principally, of calc spar and hornblende.

The small intrusion of granite which comes to the surface between various masses of porphyry near Schmiedefeld contains at the Krux Mines, west of the village, some irregular deposits of iron ore; the surrounding rock, which is hornblendic granite, appears to be associated with a sort of greenstone. The most important of these deposits is that known as the Schwarze Krux, sometimes consisting of nearly pure magnetite, but occasionally more or less mixed with quartz, garnets, iron pyrites, copper pyrites, mispickel, specular iron ore, and fluor spar. The Rothe and the Gelbe Krux, near the Schwarze Krux, contain somewhat similar deposits, which consist partly of hæmatite and partly of magnetite, often, however, much mixed with iron pyrites.

The quartz-porphyry, as well as the mica-traps and melaphyres, of the Thuringian Forest is sometimes traversed by veins of oxide of manganese, whose strike is usually parallel to the trend of the mountain ridges. These lodes, which exceptionally penetrate the granite, consist of pyrolusite and psilomelane associated with calc spar and heavy spar; with these are found wad, hausmannite, braunite, and, more rarely, manganite. The principal veins yielding ores of manganese occur in the Rumpelsberg and Mittelberg, near Elgersburg, where they usually occur without any considerable admixture of gangue. They are, however, sometimes associated with tabular heavy spar or calc spar, and the lodes not unfrequently enclose large horses of the rock in which they occur. When pyrolusite is present in a pure state, it usually forms bands parallel to the walls of the vein fissure with its crystals all directed towards the centre of the lode. The other ores of manganese are found in irregular patches, between the masses of country rock and clay, by which the lode fissures are partly filled. A few of the most important of these lodes attain a width of fifteen feet, while others can only be traced as mere lines. Their extreme depth has never been attained, although the workings on some of them have been carried fifty fathoms below the surface. The analogous deposits of pyrolusite in the neighbourhood of Ilmenau and Friedrichsroda are of less importance.

A dark-coloured slate which overlies the granite at Goldlauter, near Suhl, is of Carboniferous age, and contains thin layers of anthracite, together with impressions of ferns and stigmaria. One of the beds of this formation of a more than usually dark tint contains lenticular or ellipsoidal masses, varying from one inch to six inches in diameter, containing various metalliferous ores. These are arranged in concentric layers around a kernel generally consisting of sphærosiderite, although this is sometimes replaced by a fragment of black crystalline limestone. The kernel is usually surrounded by layers of copper pyrites, tetrahedrite, native silver, and a silvery white mineral (probably mispickel) which crystallizes in fine needles and contains a large percentage of silver. A layer of reddish-brown spar, containing but slight indications of the presence of metals, surrounds the minerals above enumerated, and over this follow alternating bands of iron pyrites, mispickel, and argillaceous shale. These ellipsoidal masses are rarely so perfect as to exhibit in any one specimen the whole of the layers mentioned, and this deposit may be regarded as possessing greater geological interest than economic value.

In addition to iron ores, the *Zechstein* of the Thuringian Forest contains *Kupferschiefer*, with veins containing ores of silver and cobalt. The most important iron deposits of the *Zechstein* occur in the neighbourhood of Herges, and are worked in the Stahlberg, Mommel, and various other mines. That they originally consisted of spathic iron ore there can be little doubt, but they have now become chiefly converted into limonite. Although their form is irregular they have a general south-east and north-west strike and appear to be frequently connected with one another, but are entirely confined to the *Zechstein*. The strata of the *Zechstein* and Bunter Sandstone formations are much dislocated, and intrusions of granite and other eruptive rocks are of frequent occurrence. *Kupferschiefer* and *Weissliegendes* appear to be wanting in the neighbourhood of Herges.

In 1879 the Thuringian Forest produced 18,680 tonnes of iron ores value £5,914; 1,273 tonnes of manganese ores value £4,677; 41 tonnes of antimony ores value £746; and 10 tonnes of copper ores value £8.[1]

THE ERZGEBIRGE.—This mountainous range constitutes an elevated plateau rising on an average from 2,000 to 2,500 feet above the level of the sea, with a gentle north-westerly slope towards Saxony and a more precipitous declivity in the contrary direction towards Bohemia. The predominant rocks of this region

[1] *Berg und Hütten Kalendar*, Essen, 1882, p. 174.

are gneiss and mica schists which, towards the north-west, gradually merge into non-fossiliferous clay slates.

These stratified rocks have been penetrated by numerous masses and dykes of granite, as well as by the so-called red gneiss; granitic and syenitic porphyry, together with various greenstones, are likewise of frequent occurrence. Basalt here and there forms small conical hills or appears in the form of dykes, while siliceous slates, covered for the most part by rocks of Carboniferous and Permian age, occur on the north-western declivity. The ore deposits of the Erzgebirge occur exclusively in crystalline schists and in igneous rocks, and although very numerous they are not exceptionally rich. They contain ores of silver, lead, zinc, copper, tin, cobalt, nickel, bismuth, antimony, arsenic, iron, and manganese, with occasional traces of gold and mercury.

The veins of silver and lead ores, which also frequently contain ores of copper, are for the most part confined to a zone extending in a north-easterly and south-westerly direction over the crest of the mountains from Meissen, through Freiberg, Langenau, Oederan, Wolkenstein, Marienberg, and Annaberg, to Joachimsthal.

The tin-ore districts, which contain the oldest metalliferous deposits of this region, are found in groups which extend along the crest of the mountains, where they form lodes, impregnations, and surface deposits. Veins of cobalt and nickel ores, frequently containing bismuth, silver, lead, and copper, occur chiefly in the neighbourhood of Schneeberg, but ores of cobalt and nickel are likewise found in the silver lodes of Freiberg, Marienberg, and Joachimsthal. Lodes of hæmatite and limonite, frequently containing manganese, lie chiefly within a zone corresponding to the crest of the mountains, but deposits of magnetite, associated with diabase and other greenstones, are distributed in groups throughout the Erzgebirge. Traces of cinnabar occur in the clay slates near Hartenstein, and ores of antimony, arsenic, and zinc, are found in numerous localities. Gold, although occasionally found in minute quantities, is no longer systematically sought after.

Mining operations in Saxony were first carried on at Freiberg;[1] some waggoners, who were transporting salt from Halle to Kuttenberg in Bohemia, having discovered pieces of galena on the road, carried them back to the Harz. This accidental discovery gave rise to mining, at what is now called Freiberg, by

[1] B. v. Cotta, "Die Lehre von den Erzlagerstätten," 2nd ed. vol. ii. p. 4. M. F. Gaetzschmann, "Die Aufsuchung und Untersuchung von Lagerstätten nutzbarer Mineralien," 1866, p. 86. C. H. Müller, "Freiberg's Berg. und Hüttenwesen," Freiberg, 1883.

miners who, in 1160, emigrated from the Upper Harz. Mining was flourishing in 1181, but, owing to famine and religious wars, many of the mines were brought to a standstill in 1521. In 1540 the town of Freiberg already contained 32,763 inhabitants above the age of eleven years, the majority of the men being miners. Great difficulties were, however, experienced in draining the mines, so that in 1569 as many as 2,100 horses and 250 men were employed in raising the water. In the beginning of the seventeenth century the richness of the mines was very great, and from the year 1529 to 1630, after subtracting the Government dues, they yielded a clear profit of £487,500. The Freiberg School of Mines was founded in 1702.

The lodes of Freiberg have been so carefully studied by B. v. Cotta, who passed a large portion of his life in the neighbourhood, and who may be regarded as the best authority upon this subject, that I shall mainly confine myself to a *résumé* of his description of the veins of this region.

The ore district comprises the area lying between Nossen, Oederan, Erbisdorf, and the stream known as the Bobritzsch, consisting predominantly of gneiss, but which is towards the west overlain by mica schists and clay slates. These schistose strata are traversed by various eruptive rocks, some of which have become converted into serpentine. Both red and grey gneiss occur in the neighbourhood around Freiberg, and frequently alternate with one another in almost parallel layers. The stratification and foliation of these rocks are nearly horizontal, but they gradually fall away in two opposite directions so as to form a gently sloping saddle. The red gneiss is usually poor in lodes. The grey or normal Freiberg gneiss is a compound of orthoclase, quartz, and dark-coloured mica with a distinctly foliated structure, readily separating it into parallel tables. Both the red and grey gneiss may be divided into a number of subordinate varieties, and sometimes include strata of other micaceous rocks. The lodes, of which about 900 are known to exist in the Freiberg district, have, in accordance with the nature of their several veinstones, been classified as follows:—

1. Noble Quartz, or Braünsdorf Formation.
2. Pyritic Lead Formation.
3. Noble Lead, or Brand Formation.
4. Barytic Lead, or Halsbrücke, Formation.

B. v. Cotta regards this as being also very nearly the order of their respective ages, for, although there is little doubt that the veins first mentioned are the oldest, the difference in age between

1, 2, and 3, would appear to be very slight; if not even somewhat variable. There can be no doubt, however, that the barytic formation is the most recent. In addition to the foregoing the so-called copper formation must not be omitted, although it can only be regarded as a modification of the pyritic lead formation in which copper ores happen locally to predominate.

1.—The lodes of the Noble Quartz Formation consist principally of white quartz or hornstone, containing numerous fragments of country rock, from which the quartz frequently radiates as from a centre. The ores usually occur in geodes only, although, more rarely, they are found disseminated throughout the veinstone. They consist of very rich argentiferous minerals such as native silver, argentite, pyrargyrite, argentiferous mispickel, tetrahedrite, miargyrite, stephanite, and polybasite. Blende, galena, and iron pyrites occur in very small quantities, as do also some other minerals, such as calc spar, brown spar, heavy spar, and fluor spar, which crystallize in drusy cavities. In addition to the foregoing, the following minerals are mentioned by v. Cotta as occurring in lodes belonging to this formation, namely:—Gypsum, strontianite, pearl spar, diallogite, cerussite, metaxite, hypochlorite, antimony ochre, valentinite, geocronite, boulangerite, zinckenite, stibnite, kermesite, heteromorphite, berthierite, bournonite, copper pyrites, millerite, pyrostilpnite, limonite, specular iron ore, and alabandite.

Some of these lodes attain a width of seven feet, and the quartz, which forms the principal portion of the gangue, is always firmly united to the country rock. Near Bräunsdorf, where the lodes of this class are most characteristically developed, they have been found workable only in the *schwarzen Gebirge*, a black, bituminous schist; they are generally barren in the ordinary mica schists. In the vicinity of Höckendorf, on the contrary, they are not unfrequently very rich in the grey gneiss.

About 150 lodes belonging to this class are known to exist in the Freiberg district, among which the following may be cited as being the most characteristic. The Verlorene-Hoffnung and Segen-Gottes lodes of the Neue-Hoffnung-Gottes Mine near Bräunsdorf; the Peter and Neuglück of the Alte-Hoffnung-Gottes Mine at Kleinvoigtsberg; the Wolfgang lode of the Segen-Gottes Mine near Gersdorf; the harder branch of the Reinsberg-Glück at the Emanuel Mine at Reinsberg, the softer branch of that double lode belonging to the pyritic lead formation; the Helmrich vein of the Romanus Mine near Siebenlehn; and, finally, the Gottlieb Lode of the Gesegnete Bergmanns Hoffnung at Obergruna.

2.—The lodes of the Pyritic Lead Formation contain various metallic sulphides enclosed in a quartzose gangue; the principal metalliferous minerals being argentiferous galena, blende, iron and copper pyrites, and mispickel. In some cases ores of copper so preponderate as to give rise to what has been called the copper formation. Rich silver ores, calc spar, heavy spar, fluor spar, &c., occur in very subordinate quantities only, and are usually found in the form of crystals lining the interior of drusy cavities, where they are evidently a more recent formation. The following other minerals, many of them of secondary origin, have been found in lodes belonging to this class. Hornstone, opal, gypsum, cerussite, pyromorphite, malachite, azurite, tyrolite, pharmacosiderite, scorodite, pharmacolite, cobalt bloom, pitticite, copperas, nacrite, allophane, chlorite, chrysocolla, scheelite, atacamite, stilpnosiderite, lampadite, melaconite, limonite, cuprite, specular iron ore, traces of cassiterite in blende, native silver, native copper, redruthite, stromeyerite, bournonite, polybasite, argentite, freieslebenite, tetrahedrite, tennantite, erubescite, pyrargyrite, and marcasite. The outcrops of such lodes are often much decomposed, and exhibit well-defined and abundant gossans. This formation is most extensively developed to the northeast of Freiberg, several lodes belonging to this class being worked in the Himmelfahrt Mine. Among the 300 lodes enumerated by v. Herder as belonging to this formation the following may be regarded as characteristic, namely, the Frisch-Glück, Gottlob, Abraham, and Jung-David lodes of the Himmelfahrt Mine; the Laura and Abendstern of the Neuer Morgenstern Mine; the Jung-Andreas of the Krönor Mine, and the Leander of the Alt-Mordgrube.

As already stated, the so-called copper lodes are merely a modification of the pyritic lead formation, containing, in association with quartz, various copper ores, such as copper pyrites, redruthite, erubescite, tetrahedrite, &c., and, as products of decomposition, malachite, azurite, cuprite, &c. The Gottlob, Franzer, and Heinrich lodes of the Morgenstern Mines are cited as examples of this modification.

3.—The predominating gangue of the lodes belonging to the Noble Lead Formation consists principally of various carbonates, especially brown spar and diallogite, associated with quartz. The most important ore is galena, which is somewhat richer in silver than is that of the preceding formation, and often forms the middle layer of symmetrically formed lodes which, in addition, contain blende and iron pyrites. These are, more frequently than in the pyritic lead formation, accompanied by rich silver ores such as pyrargyrite, argentite, native silver, stephanite, &c., and are associated with various minerals of less commercial importance. Among these may be mentioned hornstone, opal, fluor spar, gypsum, heavy spar, calc spar, pearl spar, spathic iron ore, cerussite, pyromorphite, nacrite, cerargyrite, limonite, arsenious oxide, specular iron ore, rutile, pitch blende, arsenic, polybasite, acanthite, freieslebenite, tetrahedrite, copper pyrites, mispickel, and realgar.

Von Herder has enumerated about 340 veins as belonging to this formation, which are found chiefly in the neighbourhood of Brand and Erbisdorf. The Traugott, Carl, Ludwig, Hülfe-Gottes, and Gottholder lodes of the Beschert-Glück Mine, and the Felix and David lodes of the Himmelsfürst, are characterized by the presence of diallogite and brown spar. On the other hand, the gangue of the following lodes is more largely composed of quartz or semi-opal with proportionately little brown spar, namely, the Segen-Gottes, Benjamin, and Gesellschafts-Freude of the Einigkeit, and the Beschert-Glück of the Himmelsfürst Mine.

4.—Heavy spar forms the predominating and characteristic veinstone of the lodes of the Barytic Lead Formation, in which it is symmetrically arranged in parallel layers between which occur thin bands of galena, blende, pyrites, quartz, and fluor spar. The centre of the lode sometimes contains large drusy cavities in which occur the above-mentioned minerals associated with rich silver ores and various beautifully crystallized carbonates. In addition to the foregoing characteristic minerals the lodes belonging to this class contain the following, namely; agate, opal, gypsum, pseudomorphs after apatite, calc spar, pearl spar, brown spar, spathic iron ore, cerussite, pyromorphite, erythrine, nacrite, beryl, chloropal, cerargyrite, limonite, specular iron ore, pitchblende, native silver, arsenic, bismuth, clausthalite, bournonite, stephanite, polybasite, argentite, tetrahedrite, copper pyrites, cobaltine, smaltine, copper-nickel, millerite, pyrostilpnite, pyrargyrite, and realgar. Portions of these lodes are not unfrequently found to have become brecciated through the repeated opening of the vein fissure, and fragments of comby veinstone which have thus become detached, have been reunited in positions very different from those which they originally occupied. A concentric banded structure, resulting in cockade ores, is by no means unfrequent in these lodes, some of which are as much as seven feet in width. The Halsbrücke vein may be regarded as the finest example of a vein belonging to this formation. Von Herder enumerates about 130 veins as being of this class.

The lodes belonging to these different formations do not, however, always exhibit any distinct or characteristic peculiarities, and in some cases their classification becomes extremely difficult, since minerals of comparatively recent age are often found associated in the same veins with others belonging to a much earlier period. This may probably be explained either by a previous incomplete filling of the fissure, or by its having been repeatedly re-opened.

These lodes, which are distributed in nearly parallel zones, have been classified by v. Beust[1] into the four following groups, in accordance with the direction of their strike.

a. The first group consists of a number of lodes whose strike is from north-east to south-west, with a nearly perpendicular dip, so that the layers of gneiss, which are almost horizontal, are cut through nearly at right angles to their bedding. Their veinstone belongs partly to the Noble Lead Formation and partly to the Pyritic Lead and Copper Formation.

b. The strike of lodes belonging to the second group is nearly from north to south, and the dip is much less considerable than that of the lodes above described. They form two nearly parallel bands, the one south of Freiberg, between Striegis and the Three Crosses, and the other between the town of Freiberg and the River Mulde. The matrix of the more southerly group belongs principally to the Noble Lead Formation, while that of the other, on the contrary, belongs to the Pyritic Lead Formation. Both of these intersect group *a* at acute angles, and give rise to a local enrichment of the ores.

c. A third principal strike is from south-east to north-west; the lodes coursing in this direction nearly all belong to the Pyritic Lead Formation, and are scattered over a considerable area between Langenau and Freiberg. On the south-west of Freiberg they dip, for the most part, towards the south-west, but on the north-east of that town their dip, although almost perpendicular, is towards the north-east. They intersect and frequently displace the groups *a* and *b*, such intersection being often characterised by an increase in the richness of the ores.

d. The fourth group, of which the strike is north-east and south-west, and the dip north-west, consists of lodes belonging to the Noble Quartz Formation, comprised within a band, fifteen miles in length and five in breadth, extending from Nossen and Oederan to the north-west of Freiberg. Although these lodes in their general

[1] v. Beust, *Berg. und Hüttenm. Zeitung*, 1881, p. 377.

direction resemble those of class *a*, they have a very different matrix, and their direction is somewhat more variable.

In addition to the foregoing predominating directions of strike many of the lodes in the Freiberg district follow intermediate courses, and therefore cannot be classified under either of the preceding groups. Isolated veins frequently occur towards the limit of the mining field, especially in the neighbourhood of Frauenstein, Ammelsdorf, Höckendorf, and Dippoldiswalde. Throughout the whole district the ground in the vicinity of the principal lode-junctions has been that most extensively worked. The whole of the lodes in the district around Freiberg, with perhaps the exception of those belonging to the Barytic Lead Formation, appear to be in some way in connection with the dykes of quartz-porphyry which traverse the gneiss of this region, and are usually intersected by the lodes. Boulders of this porphyry are found in the neighbouring upper *Rothliegendes*, while tuffs, apparently resulting from eruptions of the same rock, are found in the lower *Rothliegendes* of the same district; it is therefore probable that the Freiberg lodes belong, as a whole, to the period of the upper *Rothliegendes.*

The deepest sinking in the Freiberg district is at the Abraham shaft at the Himmelfahrt Mine, which is 297 fathoms deep; the average depth of the other shafts being about 165 fathoms.

In the year 1881 the Freiberg district produced 27,594 tonnes of ore, worth £211,221.[1] The Himmelfahrt, the most important of the Freiberg mines, yielded 13,235 tonnes of silver, lead, and copper ores, worth £66,110. The Himmelsfürst Mine at Brand produced 6,613 tonnes of ore, worth £61,164. The Vereinigt-Feld Mine at Brand produced 1,323 tonnes of ore, worth £8,496.

Silver ore was discovered at Schneeberg[2] in 1410, but the mines were not worked until 1471, when, owing to rich discoveries having been made, miners flocked in great numbers from all sides in such a way that the new town on the Schneeberg, in the course of a few years, numbered 12,000 inhabitants. The richest mine was the St. George which, in 1477, yielded ore from which twenty tonnes of silver were obtained. The yield of the Schneeberg must, in the first thirty years, have been very large, and from the year 1471 to 1500 it is said to have yielded more than 160 tonnes of silver. In 1482, 166 mines were at work upon the Schneeberg, and the ore obtained was smelted at Zwickau.

[1] *Jahrbuch für das Berg und Hüttenwesen im Königreiche Sachsen*, 1883, p. 19.

[2] H. Müller, *Cotta's Gangstudien*, vol. iii. p. 1. B. v. Cotta, "Die Lehre von den Erzlagerstätten," vol. ii. p 46. *Jahrbuch für das Berg und Hüttenwesen im Königreiche Sachsen*, 1883, p. 67.

The yield of silver, however, rapidly decreased during the sixteenth century, and the production is now insignificant. On the other hand, the mining of cobalt ores, which were discovered in 1561, still continues to be of some importance.

The Schneeberg consists of large masses of granite surrounded by mica schists and clay slates. The lodes usually occur in these rocks, but are more rarely found in granite, their strike being so variable as to result in a perfect network of veins. According to their composition and relative ages H. Müller distinguished:—1. Copper ore veins. 2. Quartz veins destitute of ore. 3. Pyritic lead veins. 4. Barytic veins. 5. Cobalt veins. 6. Iron ore veins. (1.) The copper veins strike N. 15° to 60° E., dip to north-west, and contain quartz with copper pyrites, erubescite, fahlerz, &c., and sometimes galena, blende, iron pyrites, and arsenical pyrites. (2.) The quartz veins strike from N. 60° to 75° E., dip from 45° to 80° north-west, and very rarely contain ores. (3.) The pyritic lead veins strike from north-west to south-east, and dip to south-west; they contain quartz, pyrites, blende, and galena. (4.) The barytic veins yielded, in the fifteenth and sixteenth centuries, astonishing riches in silver ore. They strike from north to south, dip at a considerable angle, and contain heavy spar, fluor spar, calc spar, quartz, silver, lead, cobalt, nickel, and bismuth ores. (5.) At Schneeberg the cobalt veins are now the most important. They are nearly 150 in number, and their direction is very various. These veins contain quartz, hornstone, with, more rarely, calcite and brown spar, also cobaltine, native bismuth, iron pyrites, galena, pyrargyrite, native silver, and various other minerals, some of which, particularly ores of uranium, are rare. (6.) The iron lodes sometimes attain a thickness of ninety feet, and are filled with hornstone, quartz, amethyst, compact hæmatite, and brown and yellow iron ores. The veins occur on the borders of the granite or porphyry and the crystalline slates. Similar lodes occur at Marienberg, Annaberg, Joachimsthal, Johanngeorgenstadt, and other localities in the Erzgebirge. A. v. Groddeck considers these lodes as typical examples of veins which contain cobalt and nickel ore, rich silver ores, various gangues, and numerous subordinate minerals.

The Schneeberg mines during the year 1881 produced in the aggregate 158 tonnes of nickel and cobalt ores, of the total value of £5,902, together with 1,315 tonnes of silver ore, and 59 tonnes of bismuth ore, worth £3,292 and £16,933 respectively.

Mining was commenced at Marienberg[1] in 1521, on a plateau of gneiss lying between the Bockau, the Schletten, and the Zschopau rivulets. This gneiss is traversed by veins containing silver and tin ores, which vary in width from two to thirty inches, and which traverse one another in such a way as to form a complicated network. About 140 silver veins are known at Marienberg, of which the gangue consists of decomposed gneiss, clay, quartz, fluor spar, and heavy spar, which, in addition to various ores of silver, contain copper ores, galena, blende, and ores of cobalt and nickel. The tin veins, which were formerly worked chiefly in the Martersberg and Wildesberg, are essentially composed of quartz and clay in which oxide of tin is sparingly disseminated. At the end of the seventeenth century about twenty-five tonnes of tin were annually produced at Marienberg; in the middle of the last century the annual production was only 15 tonnes, from which time up to 1850, when operations were suspended, the production did not exceed 10 tonnes per annum. No tin was produced in 1881, but 111 tonnes of silver ore, worth £7,649, were obtained from the Vater Abraham Mine at Marienberg.

Near Annaberg the gneiss of the Pöhlberg is frequently broken through by basalt, by which rock in some places it is also overlain. Several silver veins occur in this locality, and many of them have been extensively worked. The lodes, of which the strike is nearly east and west, are usually only a few inches in thickness, and have a gangue composed of quartz and fluor spar, with occasionally a little heavy spar. In these veins are found native silver, pyrargyrite, and argentite, together with ores of cobalt, nickel, and copper. Numerous remains of ancient tin-streams may still be traced in the wooded district south of Annaberg.

The Schwarzenberg district[2] consists chiefly of mica schists through which protrude various masses of granite which are generally surrounded by gneiss, and are frequently traversed by greenstones and by other eruptive rocks. The ore deposits of this region, now of comparatively small commercial importance, consist of bed-like veins associated with greenstones, and containing small quantities of many different ores, and of various lodes of hæmatite.

[1] H. Müller, *Cotta's Gangstudien*, vol. iii. p. 290. *Jahrbuch für das Berg und Hüttenwesen im Königreiche Sachsen*, 1883, p. 34.

[2] Oppe, *Cotta's Gangstudien*, vol. ii. p. 132. B. v. Cotta, "Die Lehre von den Erzlagerstätten," 2nd ed. vol. ii. p. 37. *Jahrbuch für das Berg und Hüttenwesen*, 1883, p. 67.

In the neighbourhood of Johanngeorgenstadt and Eibenstock there are numerous veins and branches, chiefly in the granite, containing iron ores with a little oxide of tin, while in the mica schist of the Fastenberg there are veins containing silver and cobalt. The strike of the tin lodes is very variable and their dip in every way irregular; their filling closely resembles granite, and tin ore, when present, generally occurs either in pockets or in ribbons. In addition to ores of iron and tin these veins contain many subordinate minerals, including wolfram and molybdenite, with occasionally galena and native gold. In the vicinity of metalliferous greenstones the veins of this district contain ores of silver, cobalt, and bismuth.

The lodes producing iron ores sometimes occur singly, but are at others associated in groups, one of the most important of which intersects the mass of granite a little east of the town of Eibenstock. They also frequently occur as contact deposits between granite and mica schist, and are more numerous in the granite than in the latter rock, which they, however, sometimes follow along its line of strike. As subordinate minerals these veins contain various ores of copper and bismuth, and in 1834 seams of anthracite, sometimes as much as five inches in thickness, were found extending for a distance of nearly forty feet in a lode of hæmatite at the Lorenz Mine, at Rehhübel. The lode at this point consisted principally of fragments of granite, schist, quartz, hornstone, &c., embedded in clay, and the anthracite appears to have been derived from the adjoining mica schist which, locally, contains seams of coaly matter, fragments of which had fallen into the vein-fissure, together with pieces of the country rocks. The texture of these lodes is irregular and granular, and they seldom show any indication of a comby structure; the wall rock is often strongly impregnated with iron for a great breadth on either side of the vein.

In the year 1881 the Johanngeorgenstadt mines produced $2\frac{3}{4}$ tonnes of bismuth ore, worth £1,933, this being the sum of the production of five different mines.

The tin-producing district of Altenberg and Zinwald[1] is situated in the Saxon Erzgebirge, between Freiberg and Teplitz.

Tin was discovered at Altenberg in 1458, and for a number of years from 250 to 300 tonnes of metallic tin were produced annually. The production from 1516 to 1523 was, on an average, 175 tonnes of tin per annum. This decreased about the middle of the sixteenth century to only 100 tonnes. The Altenberg tin

[1] H. Müller, *Berg. und Hüttenm. Zeit.* 1865, p. 178; E. Reyer, "Zinn," 1881, p. 6.

stockwork is a peculiar mass of granite continuing to an unknown depth, surrounded by quartz-porphyry, granitic porphyry, and granite. The technically important part of the deposit is the *Zwitter* or stockwork-porphyry which is a dark-coloured rock consisting of quartz, mica, and finely divided tinstone; in addition to these, arsenical pyrites, copper pyrites, iron pyrites, iron glance, wolfram, native bismuth, fluor spar, and other rarer minerals are found in veins. As there is neither a felsitic ground-mass, nor are any large crystals separated out, the name *Stockwerks-porphyr* used by the miners is petrographically unsuitable, and the name *Zwitter* (tin-stuff) is to be preferred. This rock is said to yield from ½ to ⅓ per cent. of tin ore, and is traversed in all directions by quartz veins, which contain, in addition to the minerals of the *Zwitter*, molybdenite, bismuth glance, &c. They also contain red clays, quartz, and a little tin ore. The wall rock, whether consisting of granite, syenite, porphyry, or other material, is always stanniferous. These veins, often reaching a thickness of four inches, dip at a great angle, and form groups which traverse the stockwork and reach the adjacent porphyries and granites, where they are worked as isolated lodes.

The production of the Altenberg and Zinnwald districts in 1880 amounted in value to £17,000. This included tin ore to the value of £9,105 from two mines at Altenberg, and tin ore worth £53 from a mine at Zinnwald; the remainder principally consisted of iron ores.

Geyer and Ehrenfriedersdorf in Saxony, with Platten in Bohemia, constitute the second tin district of central Europe. Tin ores here occur not only in granite, but also in fissures in the adjacent slates. The stockwork of Geyer resembles that of Altenberg, being an irregular conical mass of granite with an ellipsoidal base, enclosed in gneiss and mica schists. In the granite there are innumerable veins, varying from ½ inch to 4 inches in thickness, which form nineteen distinct groups striking N. 45° to 60° E. and dipping from 70° to 80° towards the north-west. They continue into the adjacent gneiss and mica schists, with the same strike and dip. The veins contain principally quartz, with tinstone, arsenical pyrites, beryl, topaz, apatite, and fluor spar. Manès[1] has calculated that the Geyer mines produced, during the period from 1400 to 1778, 6,730 tonnes of metallic tin. No tin ore was raised at Geyer in 1880. Ehrenfriedersdorf produced, during the period from 1490 to 1497, from 60 to 90 tonnes of tin per

[1] Manès, *Ann. des Mines*, 1824, p. 288.

annum, and, from 1507 to 1520, 50 to 60 tonnes were annually produced. In 1695, 68 tonnes were produced, and at the beginning of the last century from 180 to 200 tonnes of tin were annually raised; in 1770 the yield was only 60 tonnes. At the end of the eighteenth century the production decreased to 25 tonnes, and continued between 10 and 20 tonnes until the mine was closed in 1870.

The production of iron ores in the Erzgebirge is very small.[1] During the year 1881, the Neue Silberhoffnung Mine at Schwarzenberg produced 1,380 tonnes of iron ore worth £835, and the Rother Adler 3,608 tonnes of iron ore worth £2,128. In the Fichtelgebirge, between Stenn, near Zwickau, and Christgrün, iron ores occur in association with diabase and siliceous slates. In 1881 the Frischglück Mine at Stenn yielded 599 tonnes of iron ore worth £239, the other mines in the district producing nothing.

The value of the total production in Saxony of ores of every description, during the year 1881 amounted to £273,691.

SILESIA.[2]—About the beginning of the twelfth century, gold mining was commenced with great success at Goldberg, while copper mining at Kupferberg and Rudolstadt, and iron mining near Schmiedeberg were begun at nearly the same time. Agricola mentions the mines of Reichenstein and Altenberg, where a grey pyrites was smelted for gold and silver. In Upper Silesia the oldest mining was for lead ores at Scharley, Dombrowka, and Beuthen; it was commenced in the twelfth century, but was abandoned in 1363 on account of the increasing quantities of water. Mining was resumed in 1526 at Tarnowitz, where it was still flourishing in 1552, and in spite of the plague of that year, the mines of the district yielded no less than 5,000 marks of fine silver and 650 tonnes of lead. This industry was finally stopped by the Thirty Years' War, and was only partially resumed in 1784. In 1860 lead mining was re-commenced at Beuthen, and in 1881 Upper Silesia produced no less than 21,084 tonnes of argentiferous lead ores, representing a value of £154,617.[3]

Calamine mining at Beuthen, on which the present important zinc industry of Silesia is chiefly founded, is of much more recent date. In 1560, calamine was mined, roasted, and sent to Holstein and Sweden for the direct manufacture of brass. This industry first

[1] *Jahrbuch fur das Berg. und Hüttenwesen im Königreiche Sachsen*, 1883, p. 44.

[2] v. Carnall, *Zeitschr. Berg. Hütt. Salinenw.* vol. i. 1853, p. 3. Pietsch, *Ibid.* vol. xxi. 1873, p. 292.

[3] *Ibid.* vol. xxx. 1882, p. 182.

became important about the close of the eighteenth century, and in 1792 produced 900 tonnes of calamine. Upper Silesia yielded in 1881, from fifty mines, 553,487 tonnes of zinc ore, representing a value of £357,307, and gave employment to 9,587 workmen.[1]

The elevated plateau of Upper Silesia bordering, towards the east, on Russian Poland, is covered, superficially, by deposits of alluvium, beneath which various older formations occur in the following order, and usually without interruption:—

1. Tertiary.
2. Cretaceous.
3. Jurassic.
4. Triassic ...... { Keuper Sandstone with beds of clay ironstone. *Muschelkalk*, accompanied by deposits of zinc, lead, and iron ores. Bunter Sandstone. }
5. Carboniferous rocks containing beds of sphærosiderite.

These formations extend into Poland.

The most important metalliferous ores of Upper Silesia are calamine, galena, and iron ores in the *Muschelkalk*; ironstones in the Keuper, and sphærosiderite in the Carboniferous formation.

In Upper Silesia, and in Poland, the deposits containing zinc and lead ores are enclosed in beds of the lower *Muschelkalk*. Brown iron ore forms irregular beds and nests in the limestones and dolomites of the lower *Muschelkalk*, and with it are found ores of zinc. The most important zinc ore deposits occur in dolomites which have been deposited in troughs in the *Sohlenkalkstein* or floor-limestone of the lower *Muschelkalk*, and extend from Tarnowitz in an east-south-east direction through Beuthen into Poland. The upper Silesian zinc ores consist partly of carbonate and silicate of zinc, with compact blende, but principally of zinciferous brown ironstone, zinciferous dolomite containing iron, "red calamine," and of zinciferous clays and floor limestone known as "white calamine." In these deposits the white calamine usually forms the lower bed, and red calamine the upper. Galena occurs, sometimes in the form of grains in the dolomite, sometimes as strings, and at others as seam-like deposits either at the junction of the floor-limestone and dolomite or immediately above. The thickness of this bed is not usually more than $1\frac{1}{2}$ inch, but in places it increases to 2 feet 4 inches. It is somewhat difficult to

[1] *Zeitschr. Berg. Hütt. Salinenw.* vol. xxx. 1882, p. 176.

account for the origin of the zinc in these deposits, but Runge[1] is inclined to believe that the calamine is the result of the solution and concentration of finely divided zinc ores originally disseminated in the dolomite. The fact that the masses of calamine change into compact blende as the depth increases also suggests that the ore originally deposited was blende, which has subsequently become converted into calamine.

At the calamine mine of Cäcile in Upper Silesia the transition of compact blende into calamine has been repeatedly observed. This mine, to a depth of 25 fathoms, had yielded calamine only, while 6 fathoms deeper the ore bed was found to have an altered character, consisting, to a thickness of from 6 to 9 feet, of calamine, which was traversed by numerous strings of blende, and contained large masses of this mineral which often enclosed fragments of galena. Many specimens of ore exhibited a kernel of blende with an external covering of calamine. In 1881 this mine produced 36,789 tonnes of calamine, 8,454 tonnes of blende, and 2,369 tonnes of lead ore. In the Samuelsglück Mines at Gross-Dombrowka, in the Neue Helene Mines at Scharley, and the Marie at Miechowitz, beds of blende, 9 feet in thickness, have been discovered.

At the Friedrich Mine at Tarnowitz the galena deposits consist of many irregular bunches of ore, and the Tarnowitz miner also distinguishes a hard- and a soft-ore bed. The hard-ore bed is formed either of compact galena, usually under an inch in thickness, but sometimes swelling out to above 2 feet, or of hard dolomite containing fissures filled with compact galena. Where the soft-ore bed, which varies in thickness from 10 inches to 2 feet, occurs, the dolomite is divided into separate rounded blocks, between which is found a yellowish or brownish iron ochre, which contains galena in irregular lumps, plates, or crystals; in such cases the dolomite itself loses its light colour and becomes brown. A bed of brown iron ore is frequently found above the soft-ore bed. The brown colour of the dolomite, and the formation of the fissures occurring in it, are, without doubt, both due to the same cause, namely, the partial solution and alteration of the rock; the iron ochre and the brown iron ore being residua from this process of decomposition. The soft-ore bed sometimes appears in another form, namely, as an ochreous or bituminous clay with enclosures of galena, as in the Trockenberg and some other districts. The galena is often accompanied by cerussite, anglesite, tarnowitzite, and heavy spar, the latter mineral having been found

[1] Runge and Römer, "Geologie von Oberschlesien," 1870, p. 545.

only in a trial shaft at Stolarzowitz in beds of from 2¾ to 4 inches in thickness above the floor-limestone. This heavy spar contained galena, and was in places much disintegrated and decomposed. At the Friedrich Mine a second lead-ore bed is known, ten to fifteen fathoms above that described; it is, however, much more irregularly developed.

Altogether about 40 zinc mines were working in 1881, of which 25 produced more than 2,000 tonnes of zinc, 18 more than 5,000 tonnes, 12 more than 125,000 tonnes, 3 more than 35,000 tonnes, 2 more than 50,000 tonnes, and 1 more than 100,000 tonnes. 9,586 workmen were employed in these mines, of whom 5,044 worked underground.

The production of zinc and leads ores at the most important mines in Upper Silesia was in 1881 as follows:[1]—

Name.	Calamine.	Blende.	Lead Ore.
	Tonnes.	Tonnes.	Tonnes.
New Helene (at Beuthen)	116,754	24,724	5,287
Scharley	55,640	—	293
Bleischarley	31,857	16,861	1,927
Samuelsglück	12,617	33,736	968
Cäcile	36,789	8,454	2,639
Marie	18,789	5,781	2,239
Elisabeth	19,491	—	48

In 1881 the total production of zinc and lead ores was, calamine 453,687 tonnes, blende 99,800 tonnes; total 553,487 tonnes, value £307,307; lead ore 21,084 tonnes, value £154,617. In Silesia in 1881 there was one copper mine, Stilles Glück at Jauer; this produced 7,584 tonnes of copper ore worth £2,654. From the zinc mines of Tarnowitz in 1881, 12,608 tonnes of brown iron ore worth £2,215 were produced, and from the zinc mines of Beuthen 15,604 tonnes of brown iron ore worth £3,399.

The total produce of iron ores in Silesia, *i.e.* Oberbergamtsbezirk Breslau, was in 1881 as follows:—[2]

Description of Ore.	Quantities.	Value.
	Tonnes.	£
Clay, brown iron ores of Tertiary, Jurassic and Keuper age	2,361	640
Brown iron ores of the *Muschelkalk*	746,612	127,012
Clay ironstone and sphærosiderite of the Coal-measures.	15,031	4,945
Bog iron ore	475	47
Totals	764,479	132,644

[1] *Zeitschr. Berg. Hütt. Salinenw.* vol. xxx. 1882, p. 176.
[2] *Ibid.* vol. xxx. 1882, p. 157.

GENERAL SUMMARY OF THE PRODUCTION OF METALLIFEROUS MINERALS IN THE GERMAN EMPIRE, INCLUSIVE OF LUXEMBOURG, DURING THE YEAR 1881.[1]

Description of Ore.	Quantities.	Values.	
	Tonnes.	Marks.	£
Iron ore	7,573,771	36,085,533	1,804,277
Tin ore	164	230,293	11,515
Copper ore	523,696	14,329,898	716,495
Lead ore	164,770	19,240,334	962,017
Zinc ore	659,530	9,594,411	479,721
Iron pyrites	125,057	1,279,366	63,968
Silver and Gold ores	26,787	4,275,437	213,772
Manganese ore	13,642	470,690	23,534
Cobalt ore	191	260,111	13,005
Nickel ore	6	1,933	97
Antimony ore	77	16,702	835
Arsenic ore	867	45,430	2,271
Bismuth ore	67	245,710	12,285
Uranium ore	3	10,278	514
Wolfram	44	12,959	648
Vitriol ores	21,018	49,433	2,472
Total value of Metalliferous Minerals produced in 1881		86,148,518	4,307,426

THE AUSTRO-HUNGARIAN MONARCHY.

AUSTRIA.

THE Austrian Empire is rich in minerals of commercial value, and with respect to their great variety is not surpassed by any country in Europe. Gold, in notable quantities, is found in Hungary and Transylvania, silver occurs in the same countries and in Bohemia, while quicksilver, which is almost exclusively confined to Idria in Carniola, occurs also in small quantities in Hungary as one of the constituents of a mercurial tetrahedrite. Przibram in Bohemia and Villach in Carinthia produce lead ores; copper ore is found chiefly in Salzburg, and iron ores are mined in Western Galicia, Carinthia, Carniola, the Tyrol and Styria. Tin ore is obtained only at one or two places in Bohemia.

BOHEMIA.—Both gold mining and iron mining were extensively carried on in Bohemia previous to the Roman period,

[1] From the *Monatshefte für die Statistik des Deutschen Reichs*, vol. x. 1882, p. 1.

one of the most important of the ancient gold mines having been situated at Eule, about ten English miles south of Prague. This mine, which is known to have been in operation in 734, is said to have yielded in one year one and a half million ducats of gold, and in 1145 produced twenty-four cwts. of this metal. Silver mining began on the Birkenberg near Przibram, in Central Bohemia, in 843, where the workings are at the present time the deepest in the world. At Mies, near Pilsen, silver and lead were mined previous to the year 1100, and in 1131 the town itself was founded. The mines were abandoned during the Thirty Years' War, but were resumed in 1696, and continue in operation to the present time. The silver mines at Iglau, Nellizau, and Eylau, were first opened in 1160. In consequence of the religious wars during the fifteenth and sixteenth centuries, mining was, to a large extent, abandoned, and many miners removed to the Erzgebirge where, at Graupen, Geyer, Altenberg, Zinnwald, &c., tin ores had been discovered. Mining for lead and silver at Joachimsthal flourished at the beginning of the sixteenth century, and, in 1516, 8,000 miners were employed there. In the year 1518 a mint was erected in which the first *Joachimsthaler*, afterwards called *thaler*, whence the word *dollar*, was struck. The production of the Joachimsthal mines from 1516 to 1534 was more than 2,333,000 thalers, but here, as in the district generally, mining was for a time abandoned on account of the Thirty Years' War. Many of the mines were re-opened in 1700, and have continued in operation, with more or less success, to the present time. A copper mine, which in 1616 employed 2,000 miners, was formerly worked at Grasslitz, but was abandoned at the end of the eighteenth century and has not since been re-opened.

The town of Przibram[1] is situated thirty-one English miles south-east of Prague, upon a plateau varying from 1,650 to 1,950 feet above the Adriatic, which is traversed by various chains of hills of comparatively inconsiderable elevation. There are no documents to show when mining operations first commenced at Przibram, but according to records preserved in the municipal archives a concession to re-open the mines was granted in 1527, since which period they have been continuously worked with varying degrees of activity and success.

The metalliferous deposits of this district occur in the form of veins enclosed in the lower beds of the Silurian formation of

[1] "Notice sur quelques-unes des Principales Mines de L'État Autrichien," Paris, 1878; p. 5. "Bericht über die Thätigkeit des k. k. Ackerbau Ministeriums," *Oesterr. Zeitschr.* vol. xxix. 1881, p. 553.

Bohemia; *l'étage* A of Barrande. The rocks are, for the most part, sandstones, quartzites, conglomerates, and schists, bounded on the east and west by granite and by a narrow band of clay slates belonging to *l'étage* A. The schists of *l'étage* B rest conformably upon the older slates, and above them come the sandstones of the grauwacke, which in their turn are covered by grauwacke slates of a mean thickness of about 3,250 feet. Above the grauwacke lie the sandstone and quartzite forming the extreme limit of the metalliferous group. All these beds have a strike of north 60° to 75° east; and between the sandstone and the slates of *l'étage* B, to the west of Przibram and Birkenberg, there is a fault, containing clay, a few inches only in width, which causes an extensive displacement of the strata; its direction, which is very constant, is N. 56° E., and its dip 79° north.

The Lower Silurian rocks are traversed by dykes of diorite, and by numerous metalliferous veins which are capped with gossan and, at depths below fifty fathoms, consist to a considerable extent of argentiferous galena. The thickness of the veins varies from 1 inch to 19½ feet, and nearly the whole of those which are extensively worked appear in the grauwacke; several of them thin out and become impoverished on reaching grauwackes of greater tenacity near the surface, others, on the contrary, become richer in the vicinity of their outcrops, or where a change in the country rock takes place. Some of the veins cross the fault above referred to, and have been recognised in the schists at a great distance on the other side.

In addition to galena the veins contain blende, which is poor in silver, spathic iron ore, calcite, pyrargyrite, and tetrahedrite, while argentite and native silver are but rarely found. The galena occurs in veins, branches, and lenticular masses, or is disseminated through the compact quartzose gangue. Many of the veins have been explored for great distances, both on their strike and on their dip, without showing any decrease in richness or variation in the gangue; in fact, as a general rule, the width of the veins and the proportion of silver in the galena increase with the depth attained. The longitudinal extension of the Przibram mining area is 4,550 fathoms, the breadth 2,380 fathoms, and the greatest depth yet attained 570 fathoms. In this concession nineteen shafts are now at work, of which the two deepest are the Adalbert with a depth of 557 fathoms, and the Maria shaft with a depth of 570 fathoms. The underground workings communicate with the great drainage tunnel "Joseph II.," which is 13½ miles in length and 1,360 feet above the sea level; the total length of the galleries in these mines exceeds 152 miles.

The production of ores at Przibram from 1876 to 1881 was as follows:—

Year.	Weight of Ore.	Containing		Amount of fine Silver actually produced.
		Silver.	Lead.	
	Tonnes.	Metric Centners.	Tonnes.	Metric Centners.
1876	8,062	232·02	3,792	237·49
1877	9,200	276·18	4,443	270·14
1878	9,489	276·49	4,460	288·78
1879	10,495	292·25	4,618	293·22
1880	11,068	296·90	4,710	292·00
1881	11,953	320·24	5,021	306·46

The number of workmen employed in 1880 was 5,450.

The veinstone of the lodes which occur in the gneiss at Kuttenberg [1] is composed of quartz, felspar, and calc spar. The mines were worked so early as 1237 and yield the following minerals, namely, iron pyrites, arsenical pyrites, and blende, all containing silver, as well as argentiferous galena, copper pyrites, and various silver ores. Mining was resumed a few years since in order to supply the Przibram smelting-works with pyrites, which is required in the treatment of some of the poorer material. Through the Skalka shaft, which was only 23 fathoms deep in 1877, and 102 in 1880, three productive lodes are worked. These veins, which are for the most part tolerably wide, are in places much pinched, but hitherto the productiveness of the mine has increased with its depth. In 1881, seventy-six men were employed, and 823 tonnes of pyrites, worth £1,234, were produced.[2]

The Frischglückzeche lead lode at Mies[3] is the richest in that district, and there are but few which in addition to lead ores proper contain such a variety of other minerals. This lode, in common with all the others occurring in clay slate in the neighbourhood of Mies, has a general strike in the direction of 30° east of south and dips from 55° to 80° towards the west. In thickness it varies from a mere thread to eighteen feet and, with a quartzose gangue, contains galena, cerussite, pyromorphite, blende, iron

[1] *Oesterr. Zeitsch.* vol. xxix. 1881, p. 555.

[2] *Statistisches Jahrbuch des k. k. Ackerbau Ministeriums*, p. 61, Vienna, 1882.

[3] J. Schmuck, *Oesterr. Zeitschr.* vol. xxx. 1882, p. 282. *Statistisches Jahrbuch des k. k. Ackerbau Ministeriums*, Vienna, 1882.

pyrites, and barytes. Drusy cavities of various sizes frequently occur in this vein, and the walls of these are often covered with crystals of quartz and galena, and with those of cerussite, barytes, and blende; faultings of the lode are very rare.

In 1881 there were three mines working at Mies; these employed 510 workmen, and produced 2,370 tonnes of lead ore worth £19,564, and 322 tonnes of galena, with ·65 per cent. of silver, worth £3,247.

The quaint little town of Joachimsthal[1] lies on the southern slope of the Bohemian Erzgebirge, in a ravine of which the direction is nearly north and south. Mining is believed to have commenced in this locality during the first years of the fifteenth century, and in 1517 the number of miners is stated to have been 8,000 and the town contained no less than 20,000 souls. During the wars of the seventeenth century the production declined rapidly from an average yield of twenty-two tonnes of silver, during the first eighty years, to a mean of 96,500 oz., at which it has remained nearly stationary from the year 1595 to the present day.

The country rocks of the neighbourhood of Joachimsthal are for the most part mica schists enclosed between masses of granite. In the eastern portion of the mine, where there are some masses of included limestone, the lodes usually carry calcite as the predominating veinstone; but in the western part, where the veins are not unfrequently associated with dykes of porphyry, the gangue is almost entirely quartzose. There are seventeen veins striking north and south, and seventeen others of which the direction is east and west. It has been constantly observed that the former exhibit a tendency to become enriched where they pass through the porphyry or included limestone, while the latter set of veins are not similarly affected when they come in contact with these rocks. The ores raised contain silver, cobalt, nickel, bismuth, and uranium. In the eastern divison of the mine there are two shafts situated about 260 fathoms apart; the Einigkeit's shaft is 270 fathoms in depth, and the Kaiser Josef Shaft 180 fathoms deep.

The average annual production of ore of the eastern division during the period from 1877 to 1880 was 29¼ tonnes of ore containing 4,497 oz. silver, 198 lbs. bismuth, 878 lbs. of uranic oxide, 1½ tonnes of arsenic, and 314 lbs. of cobalt and nickel, with a little lead; representing a total value of £1,687.

[1] "Principales Mines de L'État Autrichien," Paris, 1878, p. 15. *Oest. Zeit.* 1881, p. 543.

The veins in the western division, of which the most important is the Geister Lode, are worked through two shafts, the Werner, 230 fathoms deep, and the inclined Elias Shaft of 91 fathoms on the incline, or 72½ fathoms perpendicular depth.

At Schlackenwald,[1] near Carlsbad, in North-western Bohemia, is found the continuation of the granitic outburst, in which is situated the tin district of the western Erzgebirge. But while the granites and slates in the latter district are much twisted and contorted, those of North-western Bohemia are nearly horizontal. The slates by which the granite was formerly covered have, for the most part, been removed by erosion, but in the Schlackenwald district, where the entire system has been pressed into the form of a deep trough, the slate still retains a considerable thickness. In the southern portion of this district, at Schönfeld, the granite, adjacent to the slate, consists entirely of a greisen exactly resembling the rocks of Zinnwald, and mining was here formerly carried on with considerable activity; but two small conical masses of granite north of Schönfeld and between that place and Schlackenwald, were even still richer. Of the smaller of these nothing is now known, since it has not been worked in modern times; the granite of the larger mass has, however, been continuously mined for many centuries, first by fire-setting, and afterwards by blasting. Enormous cavities were in this way formed until at last the rock crushed and the mine caved in; so that nothing is now to be seen of the granitic cone except a single pillar which was apparently found not worth working.

The production of tin at Schönfeld, near Schlackenwald, was in 1355 already considerable, and for a long time Schönfeld and Graupen were the only productive tin mines of central Europe. The working of the stanniferous rock here and at numerous other points attained a great importance in the sixteenth century. About this time, however, the production of Schönfeld fell off, and for more than half a century Schlackenwald was the most important tin mine in Europe. From the Schönfeld and Schlackenwald district 800 tonnes of tin were produced in 1550, and in 1580 Schlackenwald alone yielded from 300 to 400 tonnes. The rock at that time (1570-1660) yielded ·5 per cent. of tin. According to Reyer, mining became of less importance after 1580, and he suggests, as the probable reason for this, that the price of tin, although it had in the course of the

[1] F. Reyer, "Zinn.," 1881, p. 74.

century nominally risen, had, in comparison with the price of food, &c., considerably fallen; secondly, the depth of the mines at the end of the sixteenth century had much increased, and, lastly, the percentage of ore appears, at least as regards Schlackenwald, to have decreased with the depth, as may be deduced from the following data:—

In the year 1570	the average percentage of metal in the rock was		·5
„ 1600	„	„	·5
„ 1655	„	„	·3 to ·4
„ 1760	„	„	·3 to ·4
„ 1774	„	„	·2 to ·3
„ 1819	„	„	·2
„ 1850	„	„	·2 to ·4

At the beginning of the seventeenth century Schlackenwald produced 170 tonnes, and Schönfeld 80 tonnes, of tin per annum, but this was subsequently reduced to an annual production of 50 tonnes. Almost all the ore produced at Schlackenwald was obtained in the sixteenth century, during which period about 50,000 tonnes of tin were produced in this district, and as 300 tonnes of rock only yielded 1 tonne of tin, 15 million tonnes, or about seven million cubic yards, must have been worked to give the above yield. The whole of this rock, nearly as hard as quartz, must have been removed by fire-setting, gad, and hammer, and subsequently stamped and washed.

In Bohemia, and, in fact, in the whole of Austria, the production of tin in 1881 was confined to two mines, viz., the Maurizi Mine at Hengstererben, which produced 911 tonnes of tin-stuff, worth £935, and the Graupen Mine which produced 140 tonnes of ore, worth £3,449. The total production of Bohemia in 1881 was as follows:[1]—

	Tonnes.		Tonnes.
Gold ore	7,00	Bismuth ore	13
Silver ore	12,383	Antimony ore	187
Lead ore	2,377	Uranium ore	6
Zinc ore	10	Wolfram	62
Copper ore	20	Sulphur ore	3,011
Tin ore	1,051	Manganese ore	31
Iron ore	70,206		

[1] *Statistisches Jahrbuch des k. k. Ackerbau Ministeriums*, Vienna, 1882.

SALZBURG.[1]—Mitterberg in the Salzburg Alps, where a bedded lode is worked in Silurian clay slates, is about five miles west of Bischofshofen. The deposit may be followed along its outcrop for a distance of nearly five miles, and it appears in several places to split up into two or more leaders. The present workings extend over a length of above 600 fathoms along its strike, and are situated partly upon the main lode and partly on one of its leading branches. The thickness of the lode, which is chiefly filled with *Lagerschiefer*[2] or sericite rock, averages from six to nine feet, and contains quartz, spathose iron ore, and copper and iron pyrites. The *Lagerschiefer*, which occurs only where there are ores, has a light yellowish-grey colour, is very hard, and is perhaps a metamorphosed eruptive rock. It accompanies the lode on both sides to a width of from two to fifteen fathoms, and gradually passes into ordinary slates, its thickness being greatest near the surface, and decreasing in depth. The normal Silurian clay slate is locally known as *blauer Schiefer*. The term *wilder Schiefer* is here applied to all varieties of slate near which the ore deposit becomes compressed and unproductive. The metalliferous minerals are regularly distributed in the *Lagerschiefer*, which is likewise impregnated with pyrites, which is met with in compact masses associated with quartz. The ores are either disseminated through the veinstones, or copper pyrites and spathic iron ore occur in lenticular masses enclosed in quartz; it is to be remarked also that the longitudinal axes of these masses are not always parallel to the walls of the deposit, but are inclined towards them at varying angles. Sometimes, but not often, quartz and copper pyrites, but never copper pyrites and spathic iron ore, occur in concentric bands; arsenical fahlerz and cinnabar occur as curiosities. On smelting the ores a certain proportion of nickel is obtained.

The total production of Salzburg during the year 1881 was, gold ore 84 tonnes, copper ore 3,152 tonnes, iron ore 3,837 tonnes, and nickel ore 40 tonnes, having an aggregate value of £17,550.

TYROL.—Lead and silver were mined at the Schneeberg, thirty miles south-west of Innsbruck, in the fourteenth century, and mining for copper and silver was commenced at Schwaz in Northern Tyrol about 1409; almost at the same time mines were opened at Brixlegg, Mitterberg, and Kitzbricht. Mining at these places was flourishing in the fifteenth and sixteenth centuries, while at Schwaz,

[1] F. M. Stapff, *Berg. und Hüttenm. Zeit.* 1865, p. 6.
[2] See p. 264.

in 1519, 200,000 gulden were paid as royalty alone. At the beginning of the sixteenth century, these mines are said to have employed 7,000 workmen. Mining was abandoned during the Thirty Years' War, and was not resumed until the eighteenth century, but it never again reached its former importance. The copper and silver mines at Klausen originated in 1497.

One of the best examples of the occurrence of bed-like auriferous quartz in rocks of Palæozoic age is that of the Heinzenberg, near Zell,[1] where beds and veins of quartz are enclosed in grey Silurian clay slates. Gold is never found in the veins, while in the bed-like segregations it almost constantly occurs. Nine of these beds are known, coursing from 11° to 26° north of west, dipping at an angle of from 65° to 70° towards the south, and having a thickness varying from a few inches to six fathoms. The bed-like deposits consist of auriferous quartz and slates, the gold being either met with as dust-like enclosures, or, more rarely, in distinct leaves and grains. From a mining point of view the Friedrich bed is not of very great importance, although in former times the Anton and Johann beds were extensively worked. In the Friedrich deposit there are, however, several beds, varying from sixty to seventy fathoms in width, separated by unproductive strips, and traversing it in a diagonal direction, which contain workable gold quartz.

Since its commencement in 1628, the production of the Zell gold mines has always been very variable. From 1794 to 1815, with forty-two workmen, 120 oz. to 160 oz. of gold were annually produced, and from 1840 to 1847 the average yield was 152¼ oz. per annum. From 1848 to 1852 the annual production of gold was 184¾ oz., but in the year 1854 it increased to 212 oz. In 1866, 184 tonnes of gold quartz, 620 tonnes of rough work, and 555 tonnes of slate were raised, giving 272 oz. of gold. In 1881, thirty-one miners were at work principally exploring, so that no ore was raised.

There are four mines in the Brixlegg[2] district, namely, at Schwaz, at the Kleinkogel, Grosskogel, and at the Matzenköpfel.

At Schwaz the veins, which vary in thickness from ½ to 1 inch, occur in a grauwacke slate, and are filled with spathic iron ore, ankerite, heavy spar, galena, fahlerz, copper pyrites, bournonite, pyrargyrite, and quartz.

[1] A. R. Schmidt, *Berg. und Hüttenm. Zeit.* 1868, p. 11.

[2] F. M. Stapff. *Berg. und Hüttenm. Zeit.* 1862, p. 134. *Oesterr. Zeit.* vol. xxix. 1881, p. 576.

The Kleinkogel has been worked, without interruption, from very ancient times, and is now supposed to be nearly exhausted; The Grosskogel, like the Schwaz Mines, has been resumed after a long interruption of the operations. The Kleinkogel is situated on the southern border of the Unterinnthal, about two miles southwest of Brixlegg, where the Guttenstein limestone is traversed by numerous irregular fissures containing ores. Heavy spar associated with calc spar, ankerite, and quartz, forms the principal gangue. An antimonial fahlerz, containing quicksilver, nickel, and cobalt, sometimes traverses the heavy spar in irregular threads. Stapff endeavours to explain the deposits of ore at the Kleinkogel by an influence of the country rock. The deposits of the Grosskogel are irregular stockworks, sometimes of considerable extent, containing fahlerz, argentiferous copper and iron pyrites, heavy spar, calc spar, dolomite, and quartz.

At the Matzenköpfel, near Brixlegg, where the mining is of recent date, the lodes occur in Partnach dolomite, and contain argentiferous fahlerz, galena, and iron pyrites, with arsenides of nickel and cobalt, pyrargyrite, native silver, bituminous slate, dolomite, and calc spar. The shaft is as yet only thirty-five fathoms in depth.

From 1877 to 1880 the Brixlegg mines produced—

Ore for the smelter	1,240	tonnes.
Ore for the stamps	8,982	„
Heavy spar	646	„
Spathic iron ore	1,140	„

The Pfundrersberg, at Klausen,[1] consists of a mica schist, in which there occurs a large mass of diorite. At the contact of these two rocks is a felstone-porphyry, of which the limits are not sharply defined. Three lodes traverse these rocks with a strike between 30° north of east and due east, and dip from 60° to 80° towards the north; they are accompanied by numerous strings and exhibit the character of complex lodes sixteen fathoms in thickness. The country rock has a remarkable influence on the contents of the lodes, which are invariably richest in the diorites, where they contain argentiferous galena, blende, copper pyrites, and iron pyrites; while in the felstone-porphyry and slate galena is entirely absent, and only copper pyrites and iron pyrites occur.

[1] A. R. Schmidt, *Berg. und Hüttenm. Zeit.* 1867, p. 267. *Oesterr. Zeit.* vol. xxix. 1881, p. 577.

Immediately the lodes pass into the slates they become impoverished. This mine, on account of the scarcity of timber and other materials, is not extensively worked, and as a rule only about fifteen men are employed.

The Schneeberg[1] lies about thirty miles south-west of Innsbruck, and forms the point of intersection of several lofty mountain chains. Near its summit, 7,200 feet above the sea level, and just below the general level of the glaciers, is the Schneeberg Mine. There is reason to believe that this mine was worked for argentiferous galena and copper ores as early as the beginning of the fifteenth century. In 1486 a thousand miners were employed, but shortly afterwards the ores became exhausted, and operations were abandoned.

A new examination of this locality, in the years 1868 and 1869, led to the re-opening of the mine for the sake of the blende remaining untouched in the veins, and accumulated in large quantities both in the attle, or packing, and in the old waste heaps. Deposits of blende with galena, apparently possessing a bedded character, occur in a mica schist containing garnets, which constitutes the rock of the Schneeberg. Although however the mica schist beds in the vicinity of the mines strike with remarkable regularity directly eastward, and dip towards the north, the deposits themselves, as well as the immediately adjacent mica schist beds, have a strike to the north-east, and a dip to the north-west. They vary in thickness from 6 to 55 feet, and consist of veinstone, blende and galena, with a little iron pyrites and chalcopyrite; and ankerite, calcite, quartz, garnet, and hornblende are usually present. The workings extend for a distance of 1,200 fathoms along the strike, and to a depth of 520 fathoms on the dip. The deposits are repeatedly dislocated by faults.

The author of the official report on Austrian mines, published in 1878 in connection with the French Exhibition of that year, was of opinion that Schneeberg was capable of annually producing 7,000 tonnes of blende containing 45 per cent. of zinc, and 3,000 tonnes of galena. It however appears that these anticipations have not hitherto been fully realized, for, although between five and six hundred men are employed, the production from 1877 to 1880, inclusive, was only 3,024 tonnes of blende containing 45 per cent. of zinc, and 27,133 tonnes of mixed ores containing 25 per cent. of that metal.

1 "Notice sur quelques-unes des Principales Mines de l'État Autrichien," 1878. F. Pošepny, *Oesterr. Zeit.* vol. xxvii. 1879, p. 106.

In 1881 Schneeberg produced 4,234 tonnes of zinc ore; this increased production being due to the erection of improved dressing apparatus.

Near Kitzbühel,[1] in Tyrol, bed-like lodes occur in Silurian clay slates and grauwackes. F. M. Stapff[2] describes these deposits as *Lagergänge*, or bedded lodes; A. R. Schmidt[3] calls them *Lager*, beds.

The copper pyrites occurring in Silurian clay slates has been worked for many years at the mines of Kupferplatte, Kelchalpe, and Schattberg; the ores principally consist of copper pyrites associated with iron pyrites in a gangue of quartz and ankerite, which often attains a thickness of several yards.

At the Kupferplatte Mine, five miles south of Kitzbühel, eight parallel bedded lodes varying from 4 to 35 feet in thickness are known to exist above one another; the quartz occurring in lenticular masses in the slate, while lenticular masses of slate are found in the quartz. In this lode copper pyrites and, more rarely, iron pyrites also occur either in the form of lenticules or in disseminated grains. Where the ores are rich, the country rock is composed of *Lagerschiefer;* but where, on the contrary, they are poor, the country rock is formed of the so-called *wilder Schiefer*, which is dark with an irregular cleavage. According to Stapff, the *Lagerschiefer* and *wilder Schiefer* enclosing the ore occur in a lenticular mass in normal Silurian clay slates.

The mine of Kelchalpe is ten miles south of Kitzbühel, and is 5,050 feet above the sea level. Copper pyrites here predominates, quartz being a subordinate material.

The Schattberg Mine, half a mile south of Kitzbühel, is worked by means of two adits and an inclined shaft, of which the perpendicular depth is about eighty fathoms.

From 1877 to 1880, inclusive, the average production per annum from the Kitzbühel copper mines was as follows:—

	Rough Work.	Percentage of Copper.	Ore.	Percentage of Copper.
	Tonnes.		Tonnes.	
Kupferplatte ...	1,358	1·09	142	10·5
Kelchalpe	3,436	1·57	384	14·0
Schattberg.......	962	1·56	126	12·3

[1] *Oesterr. Zeit.* vol. xxix. 1881, p. 583.
[2] *Berg. und Hüttenm. Zeit.* 1865, p. 18.
[3] *Ibid.* 1870, p. 174.

The total production of Tyrol in 1881 was:[1]—

	Tonnes.	Value.
Silver ore	·5	£75
Copper ore	12,734	£9,522
Iron ore	1,706	£1,239
Lead ore	515	£4,822
Zinc ore	4,537	£9,965
Sulphur ore	779	£389

CARINTHIA AND STYRIA.—Certain limestones of the Carinthian Alps contain in various localities deposits of lead and zinc ores, which, notwithstanding slight differences in detail, resemble one another in their more important characteristics, and have doubtless a common origin. The principal localities where such deposits have been worked are the following, namely:—Bleiberg, Kreuth, Raibl, Windisch-Bleiberg, Kappel, Mies, and Schwarzenbach. They all occur in a belt of limestone of a few miles in breadth and about seventy-five miles in length; but it will be unnecessary to give a description of more than one of them.

The mining village of Raibl,[2] in Upper Carinthia, is situated on a declivity of the Königsberg, which contains deposits of galena, blende, and calamine, which have been worked from the earliest times. The deposits of Raibl rest conformably on the strata of the Upper Trias, and have been displaced to a distance of from twenty to thirty fathoms by faults running north and south. Near these dislocating fissures, which, at the surface, can be distinguished as valleys, the ores occur in limestone, chiefly in its upper portions; the term limestone is, however, purely a stratigraphical distinction, since these beds, 1,000 yards in thickness, are not only composed of limestone but also of various slates and dolomites. The Raibl beds, resting on the limestone, consist of marl, slate, and shale. Galena and blende occur in the dolomite, while the calamine deposits are found on a somewhat different horizon in the limestone. The deposits of galena and blende are distinctly cavities in the dolomite and dolomitic slates which have been filled by infiltration. They are very irregular in form, but always contain crystalline blende, galena, iron pyrites, and dolomite, in layers parallel to the walls of the deposit. Dolomite sometimes occurs between the galena and blende, and seems most frequently to form the central

[1] *Statistisches Jahrbuch des k. k. Ackerbau Ministeriums*, Vienna, 1882, p. 135.
[2] F. Pošepny, *Jahrb. d. k. k. geol. Reichsanst.* vol. xxiii. 1873, p. 317. *Oesterr. Zeit.* vol. xxix. 1881, p. 584.

lining of the cavity, but in some cases blende occupies this position. Heavy spar is rare, and never forms entire beds, but occurs only as separate crystalline aggregations in dolomitic geodes. The calamine deposits differ entirely from the foregoing, as in them there is nothing to indicate cavities filled by infiltration, but everything, on the contrary, seems to show that they are pseudomorphs after limestone, and certain peculiarities of this rock are accurately reproduced in the calamine. At Raibl the calamine consists, principally, of zinc carbonate and, more rarely, of zinc bloom, while silicate of zinc is very rare. The ore most plentifully obtained is a nearly pure zinc carbonate, containing on an average 45 per cent. of zinc. The production of ore in 1876 was 18,411 tonnes, but in 1880 it sank to 9,794 tonnes.

The Noric iron of Tacitus and other classic authors was prepared from ores obtained in the Styrian Erzberg, and, as this industry has, without intermission, continued in activity from the date of the Roman occupation to the present day, the aggregate yield must have been enormous. A fire, which took place at Eisenerz in 1618, destroyed documents then existing which carried back the iron manufacture to A.D. 712, but the documents still preserved do not go further back than the twelfth century. In 1871 Styria, thirty-one blast furnaces, produced 122,000 tonnes of pig iron, and during the same year Carinthia yielded 63,000 tonnes from seventeen blast furnaces.

The total production of iron ore in Styria during the year 1881 amounted to 420,974 tonnes, worth £109,042. Carinthia in the same year produced 88,041 tonnes of iron ore, worth £35,486.[1]

CARNIOLA.—The quicksilver deposit of Idria,[2] in Carniola, was discovered in 1490, or according to others in 1497, by a cooper, who formed a company for the purpose of working it; and mining was carried on by this and other companies until the Government took charge of the property in 1580. Recent investigations relative to the geology of Idria, by M. V. Lipold, the present manager, have shown that the ore-bearing rocks are exclusively of Triassic age, and that the Carboniferous sandstones and schists which form the roof of the metalliferous beds, have only assumed this position through dislocation, displacement, or reversal.

[1] *Statis. Jahrbuch*, 1882, p. 33.

[2] M. V. Lipold, "Das k. k. Quecksilber-werk zu Idria in Krain," published in 1881, to commemorate the 300th anniversary of the Government possession. *Oesterr. Zeit.* vol. xxx. 1882, p. 84.

In the north-western portion of the mine the deposit possesses the character of a bed-like vein enclosed in the so-called *Skonca* beds and conglomerates, and is of the nature of a stockwork in a Lower Triassic breccia. The ore in the south-eastern part occurs chiefly in fissures in Lower Triassic Guttenstein limestone and dolomites, both hanging and foot wall being impregnated with cinnabar. In the north-western part of the mine, in which the *Wengen* beds follow the course of the main dislocating fissure, *Guttenstein* and *Werfen* beds consisting of dolomites, limestones, and of sandy slates on which the *Wengen* beds are deposited, form the foot wall of the deposit. Above the *Wengen* beds come the *Skonca* beds, and above these are limestone-conglomerates impregnated with cinnabar, dolomitic breccia, and *Guttenstein* beds. The *Wengen* beds, which principally carry the ore, dip 42° north-east, until at a depth of 150 fathoms they split up into two branches, rising respectively for a distance of forty fathoms at angles of 34° and 47°, and then, turning downwards, are united, and assume a dip of 50° north-east. The slates are not uniformly impregnated with cinnabar, there being sometimes rich pockets and lenticular masses enclosed in barren ground. Cinnabar is the only ore occurring in depth, native quicksilver being found only near the surface.

The richest ore is the *Stahlerz* or steel ore, so called from its colour, which contains 75 per cent. of mercury, and occurs in a compact or crypto-crystalline form. The *Lebererz* is liver-coloured, compact, and lustrous, usually forming nests in the *Stahlerz*. The *Ziegelerz*, or brick ore, is sandy, granular, and of a bright red colour. A peculiar variety of the ore is known as *Korallenerz*.

The *Skonca* beds proper consist principally of dark, bituminous, dolomitic sandstones and slates, containing fossils resembling corals, which have not at present been determined; these coral sandstones and slates are sometimes productive of ore. The slates, where they carry ore, which is frequently associated with iron pyrites, are generally highly bituminous. In the south-eastern parts of the mines the strata are almost vertical, and are crossed by fissures sometimes exceeding three feet in width. The quicksilver deposit of Idria contains iron in the form of pyrites, but no other metals, and is remarkably poor in crystallized minerals; cinnabar, calc spar, dolomite, and quartz being rarely found as good crystals. Idrialite and anthracite occur in the form of compact masses.

Lipold believes that the ores owe their origin to infiltration from below, and calls attention to the fact that the mine grows richer as greater depth is attained.

From 1877 to 1879 the reduction works treated the following quantities of ore:—

1877.	33,311	tonnes containing	1·371	p.c. of mercury.
1878.	33,004	„ „	1·360	„ „
1879.	40,627	„ „	1·076	„ „

The production of quicksilver in 1877 amounted to 837,960 lbs., while the yield in 1878 and 1879 amounted respectively to 791,015 and 924,137 lbs. Within the last thirty years the production of Idria has been trebled. Among the quicksilver mines of the world, Almaden, in Spain, takes the first rank, New Almaden, in California, the second, and Idria, in Carniola, the third.

GENERAL SUMMARY OF THE PRODUCTION OF METALLIFEROUS MINERALS IN THE AUSTRIAN EMPIRE, EXCLUSIVE OF HUNGARY, DURING THE YEAR 1882.[1]

Description of Ore.	Quantities.	Values.	
	Tonnes.	Gulden.	£
Iron ore	902,510	2,397,464	239,746
Tin ore	2,602	20,063	2,006
Copper ore	4,154	229,036	22,904
Lead ore	14,765	1,172,847	117,285
Zinc ore	25,300	374,093	37,409
Sulphur ore	9,005	101,012	10,102
Gold ore	354	16,839	1,684
Silver ore	11,841	3,043,935	304,394
Nickel and Cobalt ores	14	528	53
Antimony ore	509	22,232	2,223
Bismuth ore	21	—	—
Uranium ore	6	39,144	3,914
Wolfram	66	8,936	894
Quicksilver ore	46,968	543,005	54,300
Manganese ore	8,418	74,124	7,412
Total Value of Metalliferous Minerals produced in 1882		8,043,258	804,326

HUNGARY.

Mining in Hungary dates from before the time of the Romans, when important gold mines were in operation in Dacia, the Transylvania of the present day, at Vöröspatak, Zalathna, and

[1] From the *Statistisches Jahrbuch des k. k. Ackerbau Ministeriums für* 1882. Vienna, 1883.

Offenbánya, while, in Lower Hungary, silver and copper mines were opened in the seventh century. The town of Schemnitz was founded about the beginning of the twelfth century by Frank and Saxon miners; Kremnitz is of nearly the same date, while Neusohl was founded in the fourteenth century by miners from Saxony and Thuringia. In Upper Hungary mining for silver, copper, and antimony originated at Schmöllnitz, Aranyidka, and Kapnik, by German colonisation in the fifteenth century; the gold mining at Botza, in Lower Hungary, dating from 1550. The Schemnitz mines, which still continue to be the most important, in the year 1690 produced 16,894 oz. of gold; while the production of precious metals from 1740 to 1773 was not less than seventy million gulden, and at the present time the annual production is about 16,241 oz. of gold and 378,962 oz. of silver. In Southern Hungary important lead and silver mines existed at Gvosdanska, but they were abandoned in the middle of the sixteenth century on account of the wars with the Turks.

At Schemnitz,[1] in Hungary, sixty-five miles north-west of Buda, the lodes pass in a south-westerly direction out of propylite into beds of Miocene age, thus proving that they were formed at a comparatively recent date. These lodes are characterised by great width, and by a filling consisting of decomposed and altered rocks in which the ores occur as impregnations, in threads, and as the cementing material of breccias. Distinct selvages do not occur, and the veins consequently appear rather as bands of rock impregnated with ore than as fissures which have been filled with various mineral substances. The veinstone varies considerably in the different lodes, but rocks converted into a clayey or siliceous mass, hornstone, quartz, and amethyst are of especially frequent occurrence. A peculiar quartzose rock, locally known as *Sinopel*, which is of a brownish-red colour, probably owing to the presence of iron oxide, is rich in gold besides being impregnated with argentiferous galena, blende, copper pyrites, and iron pyrites.

Among the minerals occurring in the lodes are various rich silver ores, such as native silver, polybasite, pyrargyrite, &c., which are found, principally, in veins enclosed in the syenite at Hodritsch, near Schemnitz, but also occur, although more rarely, at Schemnitz itself. At Hodritsch a small mass of syenite comes to the surface, and is surrounded on all sides by propylite. J. W. Judd and G. v. Rath question whether this rock is really a syenite,

[1] M. V. Lipold, *Jahrb. d. k. k. geol. Reichsanst*, 1867, p. 317.

but Pettko, Adrian, and Lipold are of opinion that it is so. The syenite of Hodritsch has a much greater extent beneath the surface than at the surface, and is surrounded by metamorphosed Devonian strata, and by rocks of Triassic age. The Tertiary eruptive rocks burst through the syenite and sedimentary rocks in lode-like dykes, and extend in great masses over both. Propylite is the oldest Tertiary eruptive rock found in the neighbourhood, and this, as in other Hungarian metalliferous districts, is penetrated by more recent igneous rocks. At Schemnitz dykes of rhyolite sometimes occur as productive metalliferous veins. According to Lipold, the Grüner Lode, the Johann Lode, and the Biber Lode are nothing more than veins of rhyolite which contain silver and other ores in strings and fissures, and he is of opinion that the mode of distribution of the ore would lead to the theory of a subsequent infiltration of minerals into the igneous veins. In the syenite are veins of dacite which, as they accompany the lodes, may possibly have opened the way for their formation. The relative ages of the rhyolitic veins in the propylite and of the dacite veins in syenite, yet remain to be determined; but a very large number of lodes are known to exist within the limits of these rocks. Generally speaking, the veins in syenite have a more irregular strike, namely from south-west to north-east, from north to south, and even from east to west, than have the veins in the propylite, which course principally from south-west to north-east. The dip is usually about 75° towards the south-east, but occasionally towards the north-west. Several of the veins may be followed for a great distance in the direction of their strike. The Grüner Lode can be traced for above 1,000 fathoms, and the Spital Lode for about half a mile, so that this lode, with its great thickness of twenty fathoms, is one of the largest in the world.

Among the more recent minerals found in these lodes may be mentioned calc spar, brown spar, diallogite, spathic iron ore, heavy spar, and gypsum. The ores are to a large extent concentrated in columnar or irregularly formed shoots, which differ in character not only in the various lodes but frequently also in the same fissure. In this way the north-east portions of the Spital Lode contain only gold, galena, blende, and copper pyrites, galena playing the principal part; while in the south-west portions silver ores almost exclusively prevail. The most productive lodes in Schemnitz, namely, the Grüner Lode, the Stefan Lode, the Johann Lode, the Spital Lode, the Biber Lode, and the Theresia Lode, occur in propylite.

Kremnitz,[1] eighteen miles north of Schemnitz, is one of the most ancient of the Royal Free Mining Cities of Hungary. Here a mass of propylite, surrounded by grey trachyte, is traversed by numerous veins which are so intermixed with the country rock that, in places, neither their strike nor their dip can be determined. The mass of propylite is about half a mile in length and from 1,000 to 2,000 fathoms in width, and contains finely disseminated auriferous pyrites, which becomes concentrated in the vicinity of veins and fissures. Although the deposit generally presents rather the appearance of a stockwork than of a regular lode, yet, strictly speaking, this is not a correct definition, since enclosed in the propylite are two distinct and parallel groups of lodes, coursing from north to south, which are known respectively as the Main Lode group and the Georg-Sigmund group.

The former includes the Main Lode, the Schrämer Lode, the Kirchberg Lode, the Schindler Lode, and the Katharinen Lode; these lodes are connected together by numerous flucans and

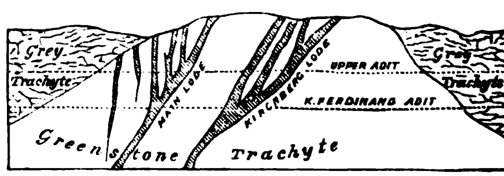

FIG. 67.—Section of lodes, Kremnitz.

branches. The lodes of this group dip from 45° to 55° east; the branches of the hanging wall, however, always incline at a greater angle than the foot wall, so that the entire system of lodes converges in depth, thus somewhat resembling an open fan. Fig. 67, after Windakiewicz, represents a section across these lodes. Their thickness varies from three to five fathoms, and, at the point where the branches meet, is sometimes as much as 50 fathoms across. The filling principally consists of quartz or hornstone with decomposed country rock, and intermixed with the quartz is finely divided argentiferous and auriferous pyrites, which imparts to it a greyish colour.

The Georg-Sigmund group consists of the Lettengang, dipping 65° west, and the Georg-Sigmund Lode, on the hanging side of the latter, dipping 70° east. The filling is, for the most part, the same as that of the previous group, excepting the occurrence in the latter of auriferous stibnite and metallic gold. Among

[1] E. Windakiewicz, *Jahrb. d. k. k. geol. Reichsanst*, vol. xvi. 1866, p. 217.

the minerals frequently found in the lodes may be mentioned quartz, calc spar, brown spar, heavy spar, auriferous and argentiferous iron pyrites, stibnite, fahlerz, pyrargyrite, and argentite; while arsenical pyrites, blende, galena, copper pyrites, and cinnabar are rare. In consequence of the decomposition of pyrites the outcrops of the lode were especially rich in gold.

At Nagybánya,[1] in South-eastern Hungary, the lodes occur in propylite, and only occasionally in grey trachyte, which is penetrated and superstratified by the former, their strike being 30° to 45° east of north. The most important of these lodes is the Kreuzberg, which courses north and south, dips from 70° to 80° west, has an average thickness of three feet, sometimes increasing to six feet, and traverses the mountain of the same name from its summit to its base. The lodes generally are not well defined and have no selvages. The filling consists of quartz, in which the auriferous pyrites, with a little copper pyrites, is finely disseminated; but nests of silver ores, especially of pyrargyrite and argentiferous fahlerz, also occur. It is remarkable that at the Kreuzberg the various carbonates are entirely absent, as are also heavy spar, galena, blende, stibnite, and realgar, which in other places are so frequently found in similar lodes. Near Nagybánya are the mines of Felsöbánya, Kapnik, and Oláh-Lápos-Bánya.

Near the village of Felsöbánya is situated the Grossgruben Mountain, which consists principally of propylite, and is at the foot surrounded by Tertiary beds. The lodes occur in this propylite striking east and west, and in the direction of their rise open out like a fan, in such a way that at the surface the group has a breadth of no less than 240 fathoms, but gradually narrows down as it gets deeper. These lodes have a thickness varying from one to twelve fathoms, and a dip of from 45° to 70°. Impure quartz containing disseminated pyrites and other minerals, is the oldest and most important veinstone, and is very rarely absent, but when it is so, realgar and stibnite often occur in fine crystals. Above the quartz come auriferous pyrites, argentiferous galena, blende, copper pyrites, stibnite, realgar, and argentite. Then follow heavy spar and gypsum; while among the most recent minerals are calc spar and brown spar.

The lodes at Kapnik[2] are very similar to those above described, but here two systems of veins are distinguished. Those of the

[1] F. v. Richthofen, *Jahrb. d. k. k. geol. Reichsanst*, 1860, p. 238. B. v. Cotta, *Berg. und Hüttenm. Zeit.*, 1861, p. 81.

[2] B. v. Cotta, *Berg. und Hüttenm. Zeit.* 1861, p. 189. H. Höfer, *Jahrb. d. k. k. geol. Reich.* 1866, p. 1.

older, like those of Felsöbánya, course east and west, and occur in a conglomerate lying at the boundary of the propylite and grey trachyte. The filling material resembles that of the parts of the Felsöbánya lodes which are poor in quartz, but when quartz is entirely wanting the ores lie directly upon the altered rock. The more recent system courses, like the Nagybánya lodes, 30° to 45° east of north, and their thickness varies from one inch to seven feet. Quartz and pyrites have impregnated the country rock, and blende and galena occur in threads. The lodes often contain large druses, in which are found the magnificent crystallized minerals for which Kapnik is celebrated.

At Oláh-Lápos Bánya the propylite has exercised a metamorphic action on the Tertiary beds, and the lodes, as far as they occur in that rock, are exactly similar to those of Kapnik; but where they traverse Tertiary strata they only contain quartz with a small quantity of pyrites.

Magurka[1] is situated on the northern border of the granitic chain, which, 4,000 to 6,000 feet above the sea, extends from Djumbir in a westerly direction, and the mine is worked at an altitude of from 2,500 to 3,000 feet. Several lodes containing stibnite, quartz, and native gold, occur in the granite; but of these the most northerly only is worked. It varies in width from a few inches to twelve feet, dips at an angle of from 25° to 30°, and is much dislocated by faults. The granite in the neighbourhood of the lode has undergone much alteration, the felspar being converted into a greenish-yellow wax-like mineral; the mica, originally dark, having become silver-white. The filling principally consists of quartz, stibnite, and granite, while argentiferous gold is finely disseminated in the quartz. Galena, blende, pyrites, brown spar and calc spar occur subordinately. At the richest points the stibnite is disseminated over a width of more than six feet, and the ore contains enclosed fragments of granite. At one point the lode is symmetrically filled in with stibnite in the middle and quartz on both sides of it, accompanied, on one side, by a brown spar string of more recent formation.

At Schmöllnitz[2] a zone of clay slate is interstratified with mica schists, and encloses beds containing patches and compact lenticular masses of iron pyrites. The clay slate zone, which is about 1,200 feet in thickness, courses from east to west, dips from 60° to 75° towards the south, and is worked for a distance

[1] R. Meier, *Jahrb. d. k. k. geol. Reichsanst*, 1868, p. 257.
[2] G. Faller, *B. u. H. Jahrb. d. k. k. Oesterr. Bergacad.* vol. xvii., 1868, p. 193.

of about three miles along its strike. In the floor and roof of the zone of clay slate, which may be regarded as the ore deposit, there is a black carbonaceous slate containing a large proportion of silica. The grey clay slates of this bed enclose two principal metalliferous zones, varying from six to sixty feet in thickness, containing pyrites; but they are not distinctly separated from the grey slates, as they always contain more or less sulphides. The ores are principally iron and copper pyrites, partly separated out as crystals in the slate, and partly as compact masses more or less associated with quartz. The latter often appear as lenticular bodies of variable dimensions enclosed in clay slates.

Three large lenticular masses of pyrites, known respectively as the Liegend-Kiesstock, the Hangend-Kiesstock, and the Engelberti-Kiesstock, are especially remarkable. The largest of these lenticular masses is the Liegend-Kiesstock, which is 210 fathoms along its strike, 75 fathoms in the direction of its dip, and 19 fathoms in thickness. The Hangend-Kiesstock may be followed for a distance of 142 fathoms along its strike, and 63 fathoms on its dip, while its thickness is 7 fathoms. The Engelberti-Kiesstock has a length of 160 fathoms, a width on its dip of 40 fathoms, and a thickness of 15 fathoms. These segregations are accompanied by shales impregnated with pyrites, and in the eastern portion of the zone traces of galena, blende, and various ores of cobalt, have been discovered.

At Herrengrund,[1] near Neusohl, very irregular deposits occur in the gneiss, mica schist, and grauwacke slates, near their junction with the granite. The mineralogical constitution of the mass is here usually as irregular as its form. The so-called Pfeifer Lode appears to be a thick vein of spathose iron ore cutting obliquely through siliceous slate, and containing fahlerz either disseminated or in strings. In the southern portion of the field bed-like lenticular masses of fahlerz associated with copper pyrites and quartz, from six to ten inches in thickness, lie between the foliations of a gneiss which passes over into a talco-micaceous schist.

At Dobschau,[2] gabbro, partially converted into serpentine, is surrounded by clay slates resting upon gneiss and granite. The lodes occur on the edge of the gabbro in the vicinity of the clay slates; they exhibit a fan-like arrangement, and possess the characteristics of composite lodes separated by no distinct boundary

[1] B. v. Cotta, *Berg. und Hüttenm. Zeit.* 1861, p. 58.
[2] G. Faller, *B. u. H. Jahrb. d. k. k. öster. Bergacad*, 1868, xvii. p. 165.

from the country rock. They sometimes attain a thickness of 24 feet, and are principally filled with country rock traversed by threads of ore. A compact mixture of copper and nickel ores is the mineral wrought; this contains from 17 to 22 per cent. of nickel, and from 4 to 10 per cent. of copper. Compact fahlerz, copper pyrites, erubescite, and nickeliferous pyrites are rare. Spathic iron ore, calc spar, and ankerite accompany the ore as gangue.

TRANSYLVANIA.[1]—The mining town of Nagyág, in Transylvania, is situated in a valley on the northern slope of a trachytic mountain range, twelve miles north-west of the town of Broos and lying between the rivers Maros and Aranyos. All the surrounding country is composed of propylite, which has burst through beds of Miocene age consisting of limestones, sandstones, conglomerates, and red clays. The propylite encloses large masses of Tertiary sandstones and conglomerates, which have experienced no apparent alteration. The lodes vary in thickness from a few inches to six feet, and their course is usually either north and south or south-east and north-west, with a dip at a considerable angle, thus forming a complicated network of veins. The ores occur in propylite, and both this rock and the enclosed sandstones and conglomerates are traversed by so-called *Glauch* lodes. This term the miner applies to eruptive masses or dykes enclosing angular fragments of the country rock, and of a peculiar slate which contains rounded patches of quartz about the size of a nut. The *Glauch* of Nagyág is a rock closely resembling dacite. The *Glauch* lodes vary from an inch to three feet in thickness, and have generally a course similar to that of the ore-bearing lodes, on the productiveness of which they apparently exercise a favourable influence. The ore-bearing veins in the hard propylite are usually thin and unproductive, but when it is less hard they are thicker and more metalliferous; in a soft country rock they are commonly much split up. They traverse both the propylite and the *Glauch*. The most important minerals found in the lodes are quartz and hornstone, brown spar, calc spar, native gold, nagyagite, sylvanite, hessite, native tellurium, oxide of manganese, blende, and iron pyrites. More rarely they contain gypsum with enclosed scales of gold, heavy spar, native arsenic, magnetic pyrites, copper pyrites, fahlerz, bournonite, galena, stibnite, plumosite, blende, realgar, orpiment, and native sulphur. In the propylite are found

[1] B. v. Cotta, *Berg. und Hüttenm. Zeit.* 1861, p. 190. H. Höfer, *Jahrb. d. k. k. geol. Reichsanst.* 1866, p. 1.

nagyagite, alabandite, diallogite, with, subordinately, galena, blende, argentiferous fahlerz, and quartz; in the conglomerates, on the other hand, sylvanite, quartz, and fahlerz are found.

Offenbánya,[1] is situated north-west of Abrudbánya, in the Transylvanian Erzgebirge, between the rivers Aranyos and Maros. Here fissures about one inch in thickness traverse much-weathered propylite, and contain free gold with ores of tellurium associated with quartz, calc spar, brown spar, diallogite, iron pyrites, blende, fahlerz, galena, native silver, and pyrargyrite. These so-called tellurium veins are obliquely traversed by others containing quartz and iron pyrites, which have a favourable influence on their productiveness.

The workings which have opened up the tellurium veins, have also passed through an adjacent granular limestone containing segregated deposits of ore. The form of these is very irregular, as they occur as nests, pockets, and threads, varying in size from the smallest patches to large segregated masses. Among the ores contained in these deposits are iron pyrites, galena, blende, sulphide of manganese, psilomelane, fahlerz, and stibnite. The principal earthy minerals are calc spar, brown spar, silicate of manganese, hornstone, quartz, and clays. Grimm[2] states that a longitudinal arrangement of the minerals within the ore mass or in the lodes and cavities, is exceptional.

The contact masses of Rodna occur under very similar geological conditions to those of Offenbánya. The district is composed of mica schist and hornblende schist, with numerous intercalations of granular limestone. Tertiary beds also occur. Numerous masses of andesite burst through these rocks, and, where they come in contact with the granular limestone, ore deposits occur enclosed in the latter rock. The size of the ore bodies is very variable; the one which is at the present time principally worked, has a vertical height of 278 feet, and a thickness of 92 feet. It has been explored for a length of 390 feet, without the end having been reached. The ore is a mixture of iron pyrites, blende, and argentiferous galena, consisting of 60 per cent. iron pyrites, 20—25 per cent. blende, and 6—8 per cent. galena, the remainder being calcite and quartz.[3] Arsenical pyrites and dolomite also occur. The ores contain gold and silver. Pošepny[4] determined the relative age of

[1] Pošepny, *Jahrb. d. k. k. geol. Reichsanst.* 1875, p. 70.
[2] *Berg. und Hüttenm. Jahrbuch. d. k. k. öster. Bergacad.* vol. xvi. 1867, p. 306.
[3] G. v. Rath, *Zeitschr. d. d. geol. Gesellsch.* vol. xxx. 1878, p. 556.
[4] *Jahrb. d. k. k. geol. Reichsanst.* 1865, p. 183, and 1870, p. 19.

the minerals to be as follows:—(1) Iron pyrites and quartz; (2) galena, blende, and arsenical pyrites; (3) dolomite and calcite. Von Beust[1] and Pošepny are of opinion that the Rodna deposit is of metamorphic origin, formed by the eruption of the andesite; while, on the other hand, Grimm[2] regards it as an ore deposit originally formed in the limestone, and subsequently split up by the eruption of the andesite.

The Transylvanian village of Vöröspatak[3] lies in a deep valley five miles north-east of Abrudbánya, and is built upon a sandstone recognised as of Eocene age. In a westerly direction the valley is closed by a crescent-shaped mountain ridge composed of a hornblendic rock generally regarded as propylite, which must be more recent than the Tertiary sandstone, which it has broken through. Towards the south rises the bare and rocky mountain ridge of Csétatje, composed of a much altered eruptive rock, probably propylite, which is impregnated with iron pyrites and traversed by innumerable irregular veins containing quartz, gold, iron pyrites, blende, fahlerz, magnetic pyrites, galena, berthierite, calc spar, spathic iron ore, &c. Black clayey masses, called *Glamm*, containing fragments of mica schist and sandstone, traverse the productive rock in the form of veins and threads. This productiveness is continued from the eruptive rocks into the adjacent Eocene sandstones, which are traversed by numberless fissures filled with quartz, auriferous iron pyrites, fahlerz, copper pyrites, calc spar, &c. Occasionally such fissures may be followed for more than 100 fathoms along their strike and 30 fathoms in the direction of their dip.

In 1873 no less than 416 mining companies were at work in the gold districts of Transylvania, giving employment to 8,369 miners who, although a considerably smaller number than was formerly employed, still made their living by this industry; in 1876, however, the number of companies was still further reduced to 383, employing 6,613 miners. In 1877 this region produced 27,870 oz. of gold, 20,108 oz. of silver, 4⅗ tonnes of copper, and 1¼ tonne of lead, of an aggregate value of £126,900.[4]

THE BANAT.[5]—The eruptive rocks of the Banat and Servia, strike generally from north to south in a zone 190 miles in length. To these rocks, which are probably diorites, v. Cotta gives the collective

[1] *Jahrb. d. k. k. geol. Reichsanst.* 1869, p. 367.
[2] *Berg. und Hüttenm. Jahrb. d. k. k. öster. Bergacad.* 1870, p. 170.
[3] B. v. Cotta, *Berg. und Hüttenm. Zeit.* 1861, p. 173. F. Pošepny, *Jahrb. d. k. k. geol. Reichsanst.* 1867, p. 99. C. Doelter, *ibid.* 1874, p. 7.
[4] *Oesterr. Zeitchr.* vol. xxvii. 1879, p. 477.
[5] B. v. Cotta, *Berg. und Hüttenm. Zeit.* 1864, p. 118.

name of banatites. They are accompanied by crystalline slates, by Jurassic rocks, and probably also by rocks of Cretaceous age. At the junction of the eruptive and sedimentary rocks, the limestones become crystalline and enclose garnets, wollastonite, and vesuvianite. Associated with these rocks are irregularly formed contact deposits which contain iron pyrites, magnetite, and a great number of other minerals; among the sulphides, iron pyrites, copper pyrites, and blende predominate. The most important and best known mining districts of this zone are those of Rézbánya, Moravicza, Dognazka, Oravicza, and Cziklova.

The deposits of Rézbánya have been well described both by Peters[1] and by Pošepny.[2] According to the latter the irregular ore deposits of this district represent cavities occurring as dislocating fissures. Peters gives a list of sixty-three different minerals occurring in these deposits.

GENERAL SUMMARY OF THE PRODUCTION OF METALLIFEROUS MINERALS IN HUNGARY DURING THE YEAR 1881.[3]

Description of Ore.	Quantities.	Values.		
	Tonnes.	Florins.	£	s.
Iron ore	465,479	1,250,263	125,026	6
Copper ore	7,889	407,302	40,730	4
Lead ore	1,386	146,061	14,606	2
Zinc ore	1,462	38,591	3,859	2
Iron pyrites	47,129	206,890	20,689	0
Silver and Gold ore	6,267	706,939	70,693	18
Ores containing Gold, Silver, Lead and Copper	96,519	676,048	67,604	16
Cobalt and Nickel ore	137	79,214	7,921	8
Antimony ore	767	84,728	8,472	16
Quicksilver ore	2	350	35	0
Manganese ore	2,832	21,308	2,130	16
Total value of Metalliferous Minerals produced in 1881		3,617,694	361,769	8

[1] *Berg. und Hüttenm. Zeit.* 1862, p. 269.
[2] *Jahrb. d. k. k. geol. Reichsant.* 1875, p. 40.
[3] Inclusive of all countries belonging to the Crown of St. Stephen, namely, Hungary, Transylvania, Kroatia-Slavonia, &c. From figures supplied by the Royal Hungarian Statistical Bureau.

ITALY.

Nearly the whole of the geological formations, both igneous and sedimentary, are, to some extent, represented in Italy, and among the former may be included the eruptive rocks now being poured forth from the volcanoes of Naples and Sicily. These different formations yield, more or less abundantly, various useful minerals. Italy contains deposits of iron, copper, zinc, argentiferous lead, quicksilver, and other ores, which are, to some extent, treated in the country, but are, for the most part, exported. These deposits usually occur either as lodes traversing the older rocks, or in lenticular concentrations interstratified with their bedding. Lead occurs in combination with sulphur as galena, while zinc, principally as carbonate or silicate, is found in the Silurian rocks of Sardinia, and also to a small extent in the Triassic dolomites of Lombardy. Copper occurs in the older slates as copper pyrites, either in beds of various thickness as at Agordo, in the Aosta Valley, in veins in the serpentines and gabbros of Tuscany and Liguria, and, lastly, in quartz veins traversing some of the older rocks of Tuscany. Quicksilver is obtained from segregations of cinnabar occurring in the Eocene rocks of the Monte Amiata. Iron ores occur in various localities; in the Aosta Valley, and in other places. In the Alps there are deposits of magnetite, which, although somewhat difficult to treat, yield an exceedingly soft iron. There are also extensive deposits of spathic iron ore in the Triassic sandstones of Lombardy, which, for the most part, yield ores rich in manganese, and, when smelted with charcoal, afford iron and steel of good quality. Brown iron ores occur in irregular veins and masses at Gualdo Tadino in the Central Apennines, and in the Atina Mountains. A limonite bed at Pazzano, in Calabria, somewhat extensively wrought by the ancients, was formerly worked by the State, and afterwards by private individuals, but was ultimately abandoned as unprofitable.

The most important iron mines are those belonging to the Government in the Island of Elba, where the ore consists chiefly of hæmatite and magnetite deposited in irregular masses along the eastern coast of the island, where the proximity of the sea affords great facilities for shipping. The Kingdom of Italy is officially divided into ten mining districts, with a central office at Rome.

The head-quarters of the ten districts are severally situated at Ancona, Caltanissetta (for the whole of Sicily), Florence, Genoa, Iglesias (for Sardinia), Milan, Naples, Rome, Turin, and Vicenza.[1]

GOLD.—A considerable number of localities in Italy were known to the ancients as producing gold, but the only mines now of any importance are those situated in North Piedmont, where veins of quartz containing auriferous pyrites are enclosed in non-fossiliferous slates and schists. The mines of this district were extensively worked in the time of Pliny, who states that the Senate limited the number of slaves to 5,000 in order to prevent a reduction in the price of the precious metal. The principal amalgamation works are situated on various streams near the foot of Monte Rosa, a considerable amount of gold having been found in the valleys of Anzasca, Toppa, and Antrona. The most important mines are those of Pestarena and Val Toppa, worked by an English company, where the ore consists of a granular auriferous pyrites.

The production of gold during the year 1881 exceeded that of the previous year by 973 oz. 5 dwt. 23 gr., and the amount realised exceeded that obtained the previous year by £1,985 15*s.* 1*d.*

The returns for 1881 were as follows:—

	oz.	dwt.	gr.		£	s.	d.
From Pestarena	5,084	0	0	value	17,522	6	5
From Val Toppa	2,165	13	7	"	8,039	19	10
	7,249	13	7		25,562	6	3

At Pestarena the average yield of bar gold per ton of ore treated was 1 oz. 3 dwt. 11 gr.; being 83·3 per cent. of the total amount present. At Val Toppa the yield of bar gold per ton was 6 dwt. 10 gr.; or 81·9 per cent. of the gold present was extracted.[2]

[1] The corps of Italian mining engineers has recently published, at the request of the Minister of Agriculture and Commerce, a collection of interesting statistics relating to the mining industry of Italy, entitled "Notizie statistiche sulla Industria Mineraria in Italia dal 1860 al 1880," Rome, 1881, a volume of more than 400 pages. This has been republished in the *Revue Universelle des Mines*, and has also been translated by C. v. Ernst, who has materially added to it from his personal notes, and by extracts from "I Tesori sotterranei dell' Italia" by G. Jervis, 3 vols. Turin, 1873, 1881. These papers appeared in the *Oesterreichische Zeitschrift*, and have been separately published, in book form, under the title of "Die Montanindustrie Italiens," by C. v. Ernst, Vienna, 1883.

[2] *Report of the Pestarena United Gold Mining Company*, December, 1881.

According to Jervis[1] there were, in 1879, twenty-eight gold mines in Italy, producing in the aggregate 9,700 tonnes of auriferous ore. In 1880 the output of the Italian gold mines had increased to 11,709 tonnes of ore, worth £23,699; as, however, the Pestarena United Mines produced in that year gold to the value of £23,580 10*s.* 10*d.* it leaves only £118 9*s.* 2*d.* as the value of the gold obtained in all the other mines in Italy.

SILVER.—The first silver ores were discovered in 1870 at the Monte Narba Mine, on the eastern coast of Sardinia,[2] where the metal occurs in the native state, as sulphide, and sometimes as horn silver, or as pyrargyrite. Silver is now obtained from the mines of Monte Narba, Giovanni Bonu, Bacu Arrodas, and Correboi, in the east, and from Perda San Oliu, in the west, of the island. At Monte Narba the lode occurs in Silurian clay slate in the vicinity of porphyry, courses from east to west, and dips 70° north. The gangue consists of quartz, calc spar, and fluor spar, associated with clays and various silicates; heavy spar is rare, and the lode contains argentiferous galena as well as true silver ores.

In 1881, 771,600 oz. of silver were obtained from the Sardinian silver mines.

QUICKSILVER.[3]—At Vallalta, in the Agordino, a pyritic segregation is worked which contains cinnabar; the mineral is poor, yielding only ½ per cent. of quicksilver. Cinnabar also occurs at Stazzema.

LEAD.—The most important lead mines of Italy are in the island of Sardinia, but there are also numerous deposits of lead ore on the mainland, although they have, in very rare cases only, given rise to mining operations upon an extensive scale. In the mining district of Turin the production of lead ore was in the year 1880 confined to the Tenda Mine, in the province of Cuneo. The ore produced is a finely granular galena, associated with copper pyrites, iron pyrites, and blende. It contains about 70 per cent. of lead with a little silver; its production in 1880 was fifty-six tonnes of ore worth £440.

In the mining district of Milan the Brusimpiano Mine is worked on a vein from three to six feet in thickness containing galena, cerussite, iron pyrites, jamesonite, copper pyrites, and malachite. The Morso Alto is a lead mine, worked upon a lode twenty inches

[1] G. Jervis, "Dell'Oro in Natura," p. 68, Turin, 1881.
[2] C. v. Ernst, "Silbererzvorkommen in Sardinien," *Oesterr. Zeitschr.* 1876, No. 9, and 1877, No. 7.
[3] *Rev. Univ.* vol. xi. p. 437, 1882.

in thickness in syenite filled with quartz and heavy spar. The galena contains 70 per cent. of lead, and is rich in silver. These mines, together with the Sotto Cavallo Mine and Casa della Miniere Mine in the province of Como, with the Lanzani Mine recently opened near Bergamo, produced, in 1880, only 684 tonnes of ore, worth £3,566.

In the mining district of Florence, the Bottino Mine is the only one which deserves mention, on account of the occurrence of argentiferous galena. In this mine, which was probably worked by the Etruscans and Romans, the lode courses from north-west to south-east with a dip of 55° south-west, and consists partly of finely granular, partly of coarsely crystalline galena, all varieties of which are equally rich in silver. Fahlerz, bournonite, and native antimony are, to a small extent, mixed with the galena, and the geodes sometimes contain crystals of rare beauty. The gangue is quartz mixed with slate. The country rock is gneiss, mica schist, or talc schist, of Palæozoic age. In 1880 the production was 661 tonnes, worth £2,355. No other lead mines on the Italian mainland are worthy of particular notice, since the production of lead ores in the Vicenza district was for the same year only 11 tonnes, worth £115.

The importance of Sardinia[1] as a lead-producing region is evident from the fact that out of the sixty lead mines now working in Italy fifty-four are in that island.

The lead mines of Sardinia may be divided into three types.

1. Ore masses interstratified in Silurian rocks, as at the celebrated mine of Monteponi.

2. Veins traversing Silurian clay slates, as at Montevecchio.

3. Lodes traversing the Silurian limestones, Malacalzetta, near Iglesias, represents this form of occurrence.

The Montevecchio, which is without doubt one of the most important lead mines of Europe, is worked on a wide quartzose lode, and upon several leaders of less importance. The former, which is called the Great Lead Lode of Montevecchio, traverses the Silurian slate, almost parallel to its contact with the granite for a distance of 600 fathoms, and its outcrop may be traced in a straight line for a distance of nearly six miles from east to west, when it bends to the south-west; it dips 70° north. The ore consists of galena mixed with blende, iron pyrites, heavy spar, siderite, and copper

[1] *Oesterr. Zeitschr.* 1872, p. 3. "Relazione del Deputato Sella alla Commissione d'inchiesta sulle condizione dell'industria mineraria nell' Isola di Sardegna, 1871," *Berg. und Hüttenm. Zeit.* 1879, p. 165.

pyrites. The thickness of this great lode varies from 75 to 100 feet. The Ingurtosu and Gennamari Mines are also worked on the same lode. At the Marganei Reigraxius Mine there are two lodes, one in Silurian limestone with a quartzose gangue and much calc spar; the other a contact lode between limestone and Silurian slate. The strike of the strata is north-north-west, and the dip south-south-west. The quartz lode courses from east to west and dips south. The upper portion was worked by the Romans, as lamps, tools, &c. have been found down to a depth of thirty-six fathoms. The strike of the contact lode is north-north-west with a dip north-north-east. The ore in this lode is poor in silver, while the quartz lode yields ore containing 70 per cent. of lead, and from 55 to 60 oz. of silver per tonne.

The lode at Malacalzetta is enclosed in Silurian limestone, and varies in width from eighteen inches to seven feet six inches; its course is east and west, and its dip 60° south. The veinstone consists of quartz and calcite with a little clay; the ore usually contains 74 per cent. of lead, and carries 40 oz. of silver per tonne. The depth of the main shaft is about ninety fathoms.

Since the year 1840, Monteponi has been one of the most important mines in Italy. The galena here occurs neither in lodes nor in regular beds but in gigantic isolated columns of several hundred yards in height, which may be followed from north 15° west to south 15° east for a distance of 100 fathoms. Fifty-seven of these columns have been worked; they mostly occur at the contact of clayey limestone with dolomite. In addition to galena and other metallic sulphides, these columns are filled with calc spar and clay. The total length of the galleries in this mine is about twenty-seven miles. In 1838 this was the only lead mine in Sardinia. From 1832 to 1848 only 300 tonnes of lead ore were produced per annum, in 1861 the production had increased to 6,382 tonnes, and in 1875 it reached 10,453 tonnes. The ore contains 70 per cent. of lead, and from 5 to 9 oz. of silver per tonne.

In the year 1860, twelve lead mines only were working in Sardinia, employing 3,425 miners, and producing 9,165 tonnes of ore. In 1870, 5,047 miners were employed, and 25,000 tonnes of ore were produced. In 1880, 36,143 tonnes of lead ore were produced in Sardinia, worth £357,376.

ZINC.—Zinc ores usually occur in Italy in association with those of lead, and this is particularly the case in the island of Sardinia.

On the mainland the mines of the Valle Seriana and of the Valle Brembana, in Lombardy, may be mentioned, but three mines only on the Italian continent are returned as productive of zinc ores.

At Argentiera, near Auronzo, on the Tyrolean frontier, zinc occurs in irregular deposits in Lower Triassic slate, and in dolomitic limestones belonging to the Middle Trias. Parré, in Bergamo, is worked for calamine containing 40 per cent. of zinc. Costa Jels, near the latter mine, has been recently opened. Up to the year 1868, the Argentiera Mine appears in the official returns with an average annual production of only 200 tonnes. In 1869 the two other mines are noticed; their production began with 120 tonnes and increased year after year until, in 1879, their yield was 8,000 tonnes.

The deposits of zinc ore worked in Sardinia by the Malfidano Company are of two kinds, but, for the most part, they partake of the character of bedded veins; this is the case at Malfidano, Genna-Arenas and Planu-Sartu. Sometimes, however, they occur as chimneys of ore bearing no apparent relation to the stratification of the enclosing limestone, excepting that they preserve the same dip, which is nearly perpendicular, as at Planeddu and Monte Reggio. The enclosing limestones are supposed to be of Silurian age. The most important of these deposits is that of Malfidano, discovered in 1865, which contains calamine, blende, galena, and cerussite, which are irregularly mingled, without any recognisable order of succession; calamine, however, predominates to such an extent as to constitute seven-eighths of the whole. The deposit of Malfidano takes the form of an immense segregation parallel to the stratification of the limestone, but its limits have not, as yet, been accurately determined. This deposit appears to have two branches, in the more important of which the calamine is generally distributed in chimneys which are parallel to the bedding of the limestone. These chimneys, which vary considerably in their horizontal dimensions, have sometimes a thickness of sixty feet. When several of these unite, which is not unfrequently the case, the ore sometimes extends in the direction of its strike for a distance exceeding fifty fathoms. In other cases the calamine is distributed in branches of varying thickness, but, in both instances, the distribution of the ore follows the dip of the strata. It is on this branch of the deposit that the mine of Malfidano, properly so-called, is situated, as the other contains but few workable deposits.

At Planeddu the deposit has the form of an inverted truncated cone, the larger base reaching the surface, where it presents an area of about 1,400 square yards; thirty fathoms from the surface, however, the area becomes reduced to 132 square yards, and below that depth there is no mineral of any importance. The ore, which appears to be to a large extent worked out, is principally earthy calamine carrying from 39 to 42 per cent. of zinc.

At Monte Reggio various concentrations of calamine occur in dolomitic limestone, and of these the mass bearing the name of "De la Route" is the most important. It measures 50 fathoms in length by 15 fathoms in width, and has been worked to a depth of 25 fathoms without reaching its inferior limit. The ore, for the most part, consists of white calamine, which is nearly pure carbonate, and of yellowish calamine, covered with crystals of silicate of zinc. With these are associated calcite and a ferruginous gossan containing a small proportion of zinc. The ores obtained from this mine are rarely or never associated with metallic sulphides. The Genna-Arenas Mine, to the west of Monte Reggio, has not been wrought to any considerable extent, but the deposit consists of lenticular masses, either isolated or connected by branches of calamine.

The Planu-Sartu concession contains two separate deposits, known as the north and south ore bodies. With the exception of Malfidano, the south body is the most important as well as the most regular deposit belonging to the company. Its general strike is north 25° east, and its outcrop can be traced for a distance of 185 fathoms, and is from 20 to 25 fathoms in width. At the surface the ore forms a series of lenticular masses, arranged like a string of beads parallel to the bedding of the enclosing limestone. In depth the walls of these ore bodies approached each other in such a way that it was at one time feared they were about to give out. Subsequent explorations, however, showed that at still greater depths there are vein-like masses of considerable thickness, and of greater regularity than are usually found in deposits of calamine. Five of these varying from 4½ to 15 feet in width have been met with, and have been remarkable for their continuity in depth; at some points they opened out to a width of nearly forty feet. The colour of the ore varies from white to nearly black, and the texture is as variable as the colour. The north body, which is parallel and analogous to the south, is comparatively unproductive.

The following statistics relative to the production of zinc ores in the island of Sardinia, will serve to indicate the progress of this industry since its commencement in 1865.[1]

Year.	No. of Mines.	Tonnes of Ore produced.	No. of Miners employed.
1865	1	449	35
1870	3	92,000	2,192
1875	13	58,165	2,315
1879	24	63,039	2,713
1880	—	67,551	—

COPPER.—In the Aosta Valley, mining district of Turin, are situated the copper mines of San Marcello, Champ de Praz, and Ollomont. The latter, which is of especial importance, was opened at the beginning of the last century; the ore being a cupriferous iron pyrites containing, on an average, 3 per cent. of copper. The deposit occurs in chloritic schist associated with granite, and is conformably stratified, its course being north-west, with a dip of 40° towards the south-west; the gangue consists of quartz, hornblende, chlorite, talc, and calc spar. The other copper ore deposits in the Alps are of no special importance. Three mines were working in this district in 1880, the production during that year being 2,404 tonnes of copper ore, worth £6,696.

In Liguria, mining district of Genoa, the mines of Monte Loreto, Le Cascine, and Libbiola, may be mentioned as fairly productive. These are worked on copper pyrites and cupriferous iron pyrites, occurring in veins of quartz and calc spar, enclosed in serpentine and diorite. The Loreto Mine was opened in 1857, and old Roman workings, of which there is no record, were then discovered. Le Cascine is worked by an English company. Libbiola has been worked since 1866. In 1874 a depth of about seventy fathoms had been attained, and the adits and levels had then a total length of 2,187 fathoms. The ore, which contains from 7 to 12 per cent. of copper, goes to Swansea.

The total production of the three copper mines in the mining district of Genoa was, in 1880, 5,662 tonnes, worth £17,095.

In the mining district of Vicenza, in the Cordevole Valley, is the ancient mine of Agordo,[2] worked on a thick deposit of

[1] "Notizie Statistiche sulla Industria Mineraria in Italia dal 1860 al 1880, Rome, 1881.

[2] B. v. Cotta, *Berg. und Hüttenm. Zeit.* 1862, p. 425. Bauer, *Oesterr. Zeitschr.* 1863, p. 101. B. Walter, *Oesterr. Zeitschr.* 1863, p. 114. A. St. Schmidt, *Berg. und*

cupriferous iron pyrites, containing a little galena and blende. The ore is enclosed in a clay slate, which becomes very quartzose near its junction with limestone or sandstone. This deposit has been followed for a length of 300 fathoms in the direction of its strike, and for above 100 fathoms on its dip. The average thickness of the mass is about sixty feet, and the ore contains 1·80 Cu, 3 Zn, 39 Fe, 50 S, 1·4 As, and SiO_2 5 per cent. This mine belongs to the Italian Government. B. v. Cotta describes the form of the deposit at Agordo as that of a "flattened sausage," and compares the light slate surrounding it with the *Skōlar* of Fahlun. A. v. Groddeck classes it with his "Pyrites bed type," which includes Fahlun, Ducktown in Tennessee, Schmöllnitz, Rammelsberg, Rio Tinto, and Tharsis.

The production of Agordo has recently been as follows:—

	Tonnes.		Tonnes.
1875	14,954	1878	11,498
1876	12,291	1879	11,039
1877	12,622	1880	14,872

The value of the production of the year 1880 was £5,719.

The copper ore deposits of the Tuscan Apennines, mining district of Florence, have given rise to various important mines. Between Genoa and the sources of the Tiber and Metaura, numerous masses of eruptive rock burst through Cretaceous and Tertiary beds on both sides of the Apennines. The latter rest conformably upon the former, but they are difficult to distinguish petrographically, although separated by the Nummulitic horizon. The eruptive rocks are gabbros and serpentines, and in the vicinity of the junction of these rocks with the sedimentary formations occurs the so-called "*Gabbro rosso*" which is weathered red by the peroxidation of iron. J. Cocchi distinguishes, in addition to the older eruptive rocks associated with the serpentines and belonging to them, always marked by the presence of diallage, a more recent serpentine enclosing no diallage, which traverses the older rocks in the form of veins. This serpentine frequently contains deposits of sulphuretted ores, especially those of copper.

The most important copper vein yet discovered is that of Monte Catini,[1] which occurs in *Gabbro rosso*, or melaphyre according

Hüttenm. Zeit. 1867, p. 243. See also v. Groddeck's paper on "Sericite Rocks," quoted on p. 264.

[1] G. v. Rath, *Zeitschr. d. d. geol. Gesellsch.* vol. xvii. 1865, p. 282. A. v. Groddeck, "Die Lehre von den Lagerstätten der Erze," Leipsig, 1879, p. 150.

to G. v. Rath, who is of opinion that the serpentine was originally a cupriferous olivine, and that, on its conversion into serpentine, dislocations and contortions in the bedding took place. The lode is enclosed in a very brittle red gabbro, and is filled with broken fragments of that rock, together with pieces of diorite, euphotide, ophiolite, and serpentine. It courses from east to west, at first with a dip of 45° north; but later, at a depth of sixty fathoms, it turns over to the south, and at this point the vein is above ninety feet in thickness. The pure ore contains Cu 32·79, Fe 29·75, S 36·15, Gangue ·86 per cent., and averages from 20 to 30 per cent. for copper; native copper also frequently occurs.

This lode was worked by the Etruscans; but under the Romans mining was less actively carried on, as the Tuscan mines could not compete with the richer workings of Spain and Cyprus. Monte Catini was also worked during the early middle ages, but was brought to a standstill by the plague in 1630, and the workings were not subsequently resumed for more than a century. The third epoch of the prosperity of this mine is of comparatively recent date.

The Etruscans, with their narrow shafts and contracted levels, penetrated only into the uppermost rich horizon; in the middle ages the workings were deeper; while recently they have reached a depth of 170 fathoms. In the year 1845, 900 tonnes of ore were produced, containing 30 per cent. of copper, and in 1850, the production reached 3,000 tonnes. Many horizons were then wrought at the same time, and several of the richest were worked out, while corresponding riches were not met with in depth. In this way the production quickly became reduced, and in 1870 the mine was stopped in consequence of a lawsuit. Since that period, however, under the direction of M. A. Schneider, the annual production again reached from 1,000 to 1,200 tonnes. According to Reyer,[1] the eruptive rock-mass with which the ore is associated, is surrounded by more recent marls, and consists principally of red gabbro, which in places becomes green and resembles serpentine; the miner, he states, erroneously calls the green eruptive masses "serpentine," and the red "gabbro." On the south flank of this igneous mass, between the eruptive rock and the marls, the famous copper deposit occurs; it courses east and west for a distance of about 300 fathoms, and is rich in ore so long as it traverses the eruptive mass.

The engine shaft is 172 fathoms in depth, passing through the eruptive rock, the ore deposit, and lastly into the

[1] E. Reyer, *Berg. und Hüttenm. Zeit.* 1882, p. 325.

older marl. The main adit is about 1,100 fathoms in length, and the lode, which is large, varies considerably in thickness.

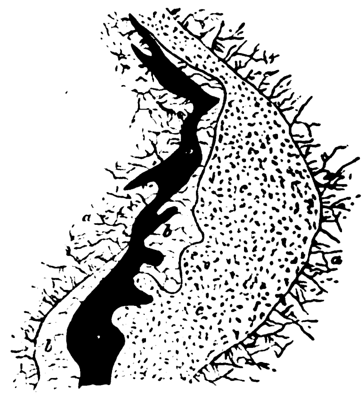

FIG. 68.—Monte Catini ; transverse section.

Figs. 68 and 69, after A. v. Groddeck, represent two vertical sections of the Monte Catini copper deposit in which *a* is melaphyre, *b* serpentine, *c* conglomerate of melaphyre and serpentine, *d* limestone and marl, and *e* masses of copper ore.

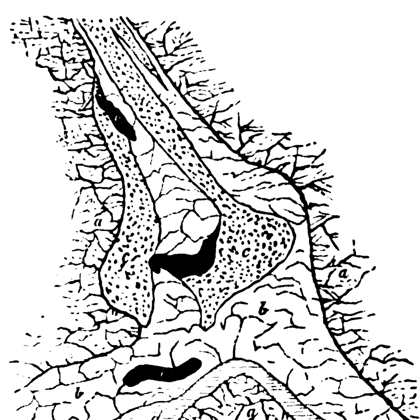

FIG. 69.—Monte Catini ; transverse section.

The Capanne Vecchie copper mine also appears to have been worked by the Etruscans, but was first re-opened 1846. The ore is copper pyrites occurring in amphibolite as country rock ; the lode courses from north to south and dips east. The ore usually contains Cu 18·01, Fe 43·33, and S 30·35 per cent., with traces of gold. Several other copper mines are working in Tuscany, but they are all of subordinate importance. The total production of the Tuscan copper mines in 1880 was 9,361 tonnes of ore worth £40,673. In 1879 thirteen copper mines were at work in Italy, employing 1,366 miners, and producing 20,751 tonnes of ore.

TIN.[1]—Early in the year 1875, during the prosecution of some excavations for hæmatite in the vicinity of Campiglia Marittima, masses of a heavy material attracted the attention of the foreman in charge of the work, who, on account of its uncommon weight, put aside a piece of the stone. Some fragments of this mineral having come under the notice of M. Blanchard, a French mining engineer, he forwarded them to London, where they were found to consist of cassiterite associated with calcite and ferric oxide. Campiglia Marittima is a small town situated about four English miles from the Tuscan coast, and thirty-five miles south-east of Leghorn. It was in one of the excavations, made either by the Etruscans or Romans, two miles south-east of Campiglia, that this discovery of cassiterite was made. This ancient mine, now know n as the Cento Camerelle, consists of a number of small excavations connected by galleries cut out of hæmitite and limestone in the flanks of Monte Fumacchio. The infiltration of calcareous waters during twenty centuries had here deposited a stalagmitic crust, of from five to ten inches in thickness, on the walls, and it is not improbable that the mine was abandoned after the destruction of Populonia by Sylla. During the middle ages no mining was carried on, and in 1858, when M. Blanchard, accompanied by M. Simonin, visited the mine, they found it inhabited by legions of bats, while on the floor had accumulated a deposit of guano, sufficient to form the object of an industrial enterprise. In 1872 M. Charlon commenced excavations for hæmatite, but in 1873 the property came into the hands of the present owners, and was worked for iron ore upon a considerable scale. A tin lode was discovered about forty-five feet west of the most extensive ancient workings. Its direction was at first nearly east and west, but it varied greatly both in size and strike, while the cassiterite was occasionally wholly replaced by hæmatite. The surrounding limestone is of Lower Liassic age, and as the excavations proceeded it was found that the cassiterite came from a horizontal bed of iron ore in which the Cento Camerelle had been excavated. On the outer borders of this the tin ore made its

[1] *Iron*, vol. xiv. 1879, p. 166; E. Reyer, "Zinn." 1882, p. 156.

appearance in irregular pockets, and in fissures in the limestone. It thus became evident that the workings might have been made for the extraction of cassiterite, and when they were at length reached, there were found, upon removing the concretions from the walls, more or less abundant traces of that mineral. In 1877 twenty-one tonnes of tin ore were obtained from this mine. Another mine on the east of the Monte Fumacchio produced, in 1877, several tonnes of tin ore of an inferior quality. These mines produced, in 1878, 31 tonnes of tin ore, worth £384, in 1879, two tonnes, worth £16, and in 1880, 16 tonnes, worth £128.

MANGANESE.—Manganese ores occur principally in Liguria, Tuscany, and the island of San Pietro on the south-west coast of Sardinia. In the first-mentioned province they occur stratified in Tertiary rocks, while at San Pietro they are enclosed in trachytic tuffs. They are, for the most part, worked in a very primitive way, and have never given rise to mining upon an extensive scale. Some of the ores of Sardinia only are of importance on account of their high percentage of peroxide. Jervis gives a list of ten manganese mines working in Italy in 1881. The Praborna Mine, in the province of Turin, is worked for hausmannite, pyrolusite, and manganite; the deposit being 24 feet in thickness and enclosed in a chloritic schist. At Cerchiera, in Genoa, the ore is amorphous, compact, of a violet black colour, mixed with some red hæmatite, and traversed by strings of calc spar, forming a bed twenty inches in thickness.

At Monte Argentario, in the province of Grosseto, a brown iron ore very rich in manganese occurs; it was extensively worked from 1874 to 1879, and the workings were resumed at the close of that year. The richer ore contains from 30 to 39 per cent. of manganese, and from 4 to 11 per cent. of iron; the poorer kind contains from 30 to 35 per cent. of iron, and about 18 per cent. of manganese. It is chiefly sent to England for making ferro-manganese.

At Capo Becco and Capo Rosso, in the island of San Pietro, there is a bed of pyrolusite twenty inches in thickness containing 60 per cent. of manganese. The ore is much in demand for chemical purposes.

IRON.—Although rich in iron ores, which were worked even in pre-historic times, Italy, on account of the want of mineral fuel, does not produce a sufficient amount of iron to meet the requirements of the country. The most important iron-mining districts are situated in Piedmont, Lombardy, and the island of Elba.

Piedmont was formerly an important iron-producing country. Veins of magnetite occur in the Aosta Valley, at Cogne, and at Traversella, which formerly gave rise not only to numerous iron mines but also to the erection of blast furnaces. The Licony Mine in the Cogne Valley is mentioned so long ago as the year 1300. This very extensive deposit varies from 66 to 98 feet in thickness, and consists, principally, of compact magnetite free from pyrites. The ore is of excellent quality and yields about 50 per cent. of iron, being interbedded between yellowish limestone and talc schist. The Larcinaz Mine lies north of the preceding, and has been opened on the continuation of the same deposit of magnetite. Spathic iron ore occurs in the vicinity of the limestone, and asbestos is found in both mines. The St. Oyen Mine, in the Great St. Bernard Valley, was worked by the Government from 1825 to 1831, but was then handed over to a private company. Both spathic iron ore and magnetite are obtained in this mine, and limonite occurs in the neighbourhood of the outcrop.

One of the most important iron ore deposits in Italy occurs in the Chiusella Valley, and is now being actively worked. In 1835 there were at Traversella in this valley 80 iron mines, which produced 7,837 tonnes of ore, yielding 3,374 tonnes of cast iron. Ten years later the production had risen to 10,000 tonnes, but subsequently again declined to 1,400 tonnes. At the present time only five mines are in operation. Crystalline magnetite with a granular structure, yielding from 40 to 50 per cent. of iron, forms the mass of the celebrated deposit of Traversella, which courses from north-west to south-east and has an almost perpendicular dip. The ore forms beds, or perhaps contact veins, in greenstone, and is accompanied by dolomite, calcite, quartz, and chlorite. A rock, containing garnets and quartz, divides the main mass of the deposit into two parts. Copper pyrites, compact iron pyrites, galena, and a great number of other crystallized minerals, which are represented in all the principal mineral collections of Europe, have made this deposit universally famous.

In 1880 the mining district of Turin produced 1,813 tonnes of iron ore, representing a value of £880.

Iron occurs in Lombardy as magnetite at Zebru and Saviore; as ochre in the older slates near Bormio, and lastly in the Triassic dolomites as spathic iron ore; the last only being of importance. This mineral occurs regularly stratified, in beds varying from a few inches to nine feet in thickness, in the lower Triassic sandstones as well as in the clay slates above them. Veins of this ore also occur beneath the Trias, but they are only of subordinate importance. The iron-ore zone extends from east to west for a distance of from nine to twelve miles into the mountains; the annual production being, on an average, about 25,000 tonnes. The most important mines are at Pisogne, in Valcamonica, in Val di Scalve, and in Val Trompia.

In Sardinia hæmatite occurs in the Silurian rocks of Acquaresi, Perdasterria, and Funtanaperda near Iglesias; magnetite in Perda-Niedda and San Leone, to the west of the Gulf of Cagliari. Of these only San Leone has attained any importance. The magnetite from this locality contains about 54 Fe, 1·12 $Si\ O_2$, ·76 Al_2O_3 and 0·105 P per cent. The main lode courses from north to south and, in the west, closely approaches the granite, which assumes the character of syenite. Jervis is of opinion that the rock accompanying these magnetite lodes is contemporaneous with the greenstones of the Alps, and especially with the serpentines. Subordinate veins of magnetite traverse the main lode from north-north-west to south-south-east, and from north-north-east to south-south-west, while at the crossings rich ore deposits occur. The width of these sometimes reaches 26 feet. On the foot wall the gangue is quartzose; while on the hanging wall is magnetite varying from 26 to 33 feet in thickness, mostly mixed with garnets. The hanging wall consists of quartzose slate, which is separated from the lode by a distinct clay selvage. As long as the ore was worked by open-cast it yielded a profit, but when an adit had to be driven, the production, which was formerly considerable, sank in 1877 to 13,300 tonnes, while in 1879 and 1880 no returns were made.

The iron ores of Elba occur in veins and more or less irregular beds along the east coast of the island, and are worked at five different mines, namely; Rio Albano, Vigneria, Rio, Terranera, and Calamita. Of these Rio Albano, Vigneria, and Rio, are the most important. The mineral consists of oxides of iron; namely, hæmatite, limonite, red iron ore, and magnetic iron ore, with siderite; the gangue is quartzose, and iron pyrites is often present. The iron ore is found in beds from 60 to 100 feet in thickness. The rock is mostly siliceous slate, which in places is overlain by limestone, the age of which has not been determined. The ore is obtained by open-cast workings, and more than 1,000 miners are employed.

The production of the different mines in the year 1879-1880 was as follows:—

	Tonnes.
Rio Albano	32,185
Vigneria	20,192
Rio	191,953
Terranera	17,909
Calamita	12,083
Total	274,322

The total production of the island of Elba in the year 1880-1881 was 403,215 tonnes. The Italian Government is, however, reported to have now restricted the exports of iron ore from Elba to 250,000 tonnes yearly.

SUMMARY OF THE PRODUCTION OF METALLIFEROUS MINERALS IN ITALY DURING THE YEAR 1880.[1]

Description of Ore.	Quantities.	Values.	
	Tonnes.	Lire.	£
Iron ore	290,974	3,127,848	125,114
Zinc ore	76,089	4,397,816	175,912
Lead ore	37,555	9,096,197	363,848
Copper ore	32,299	1,754,819	70,192
Silver ore	1,802	2,229,159	89,166
Gold ore	11,709	592,479	23,699
Quicksilver, metallic	115,940 Kg	579,700	23,188
Manganese ore	6,505 T.	214,390	8,575
Antimony ore	402	80,400	3,216
Iron pyrites	4,663	56,769	2,270
Tin ore	16	3,200	128
Total value of Metalliferous Minerals produced in 1880		22,132,777	885,308

GREECE.

But little is accurately known relative to the geology of Greece.[2] The lowest beds consist of crystalline schists and granular limestones, in which no vestige of either animal or vegetable life has

1 "Notizie Statistiche sulla Industria Mineraria in Italia dal 1860 al 1880," p. 406, Rome, 1881.

2 A. Cordella, "La Grèce sous le rapport géologique et minéralogique," Paris, 1878; *Ibid.* "Le Laurium," Marseilles, 1869; *Ibid.* "Mineralogisch-geologische Reiseskizzen aus Griechenland," *Berg. und. Hüttenm. Zeit.* 1883, pp. 21, 35, 41, 57; *Ibid.* "Description des produits des Mines du Laurium à la troisième période Olympienne," Athens, 1875; *Ibid.* "Περὶ τῶν σκωριῶν καὶ τῆς Μεταλλουργικῆς Βιομηχανίας ἐν 'Ελλάδι," Athens, 1865.

been found. After careful examination, Cordella has arrived at the conclusion that the marbles of Paros and Laurium are entirely destitute of fossils. The siliceous limestones of the Peloponnesus, forming the base of the Secondary rocks, are without fossils, and it appears to have been assumed that these crystalline sedimentary formations likewise belong to that period, the fossils which they originally contained being supposed to have become affected by the action of agencies which eventually resulted in their disappearance. The greater portion of the Cyclades, Eubœa, and a large proportion of the continent of Greece consists of such rocks, which sometimes rise to an elevation of 6,500 feet above the sea level. Among these, crystalline mica schists predominate. The metalliferous mica schist of Laurium is composed, according to recent studies of M. Szabò, of a mixture of biotite and andesine, and has a specific gravity of 2·60. M. Sauvage regards the phyllites of Mount Pentelicus as of Cretaceous age, and bases this opinion on the discovery of a fossil belemnite. Dr. Neumayer agrees with this hypothesis, having in 1873 found a Cretaceous fossil in the vicinity of the Acropolis. The numerous quarries of crystalline limestones near Laurium have not yet shown a single trace of any organism excepting a partially obliterated cast, found by Cordella, resembling a Silurian crinoid; there is consequently great difficulty in determining the age of these rocks.

The oldest known fossiliferous rocks probably belong to the Cretaceous age, and it hence appears that there must be in Greece a considerable gap in the geological succession. Silurian, Devonian, Carboniferous, Permian, Triassic, or Jurassic rocks have not been discovered. The Tertiary rocks of Greece, which are well represented, compose the northern portion of the Peloponnesus, and a large part of the mainland and of the Ionian Islands, as well as of many of the Cyclades. On account of their regularity and the number of well preserved fossils which they contain, they present a less difficult geological study than do the Secondary rocks. The most characteristic rocks of Greece are, however, of eruptive origin, principally trachytes. The plutonic rocks include granite, porphyry, and serpentine. Among the volcanic series are such rocks as obsidian, perlite, and pumice.

The mining industry of Greece, previously very limited in modern times, after being abandoned for 2,000 years began to be re-developed in 1861, the date of the promulgation of mining laws based on the French law of 1810. In 1864 a company was formed, Hilarion, Roux, & Co., to work the ancient lead slags of Laurium;

and in August, 1875, the *Société Française des Mines du Laurium* was established with a nominal capital of 13,500,000 francs.

GOLD.—Gold is found in the sands of the rivers near the town of Skyros, and in the vicinity of the village of Doliana, in the Peloponnesus there is a bed of iron pyrites containing a little gold. This metal also accompanies silver in argentiferous galena; but the known occurrences of gold alone are of no commercial importance.

LEAD, SILVER, AND ZINC.—Ores of lead, silver, and zinc, are the principal mineral products of Greece, but as they constantly occur associated in the same deposit it becomes impossible to describe them separately. Silver has not as yet been found in a native state, but occurs in association with lead in variable proportions. In the lead from the Laurium mines the average percentage of silver is greater than in that from any of the other mines of Greece. In the latter the maximum may be taken at ·25 per cent. (81¼ oz. per ton), while at Laurium the maximum sometimes reaches 1 per cent. (326 oz. 13 dwt. 8 gr. per ton), and never falls below ·1 per cent.

Argentiferous lead ores occur in mica schists, limestones, granites, and trachytes, sometimes as irregular masses, and sometimes in the form of lodes. Calamine was discovered by Cordella at Laurium in 1870, and occurs both as masses and as independent veins in limestone, being sometimes mixed with argentiferous lead ore.

The principal mineral district is that of Laurium, at the southern extremity of Attica. The rock is chiefly a crystalline schist, in which are conformably interstratified subordinate beds or irregular lenticular masses of crystalline limestone. These strata have been broken through by granite, porphyry, and by more recent igneous rocks, to the influence of which the accumulation of metalliferous minerals is generally ascribed. The ferruginous, plumbiferous, and zinciferous deposits, which have followed these outbursts, have filled fissures and cavities in the limestone, and have also accumulated at the point of contact of the limestone with mica schist, thus forming irregular masses. In mica schist the ore generally occurs in the form of veins, but it is difficult to determine whether these were formed at the same time as the metalliferous enclosures, or whether they were subsequently produced. At Camaresa, the centre of the operations of the *Société des Mines du Laurium*, one of the beds has been proved to be metalliferous over an area of a mile and a half square, and the contact deposits vary from three to twenty-two feet in thickness, while parallel ore-bearing beds are found at various levels. Four of these were known to the ancients, and the existence of others below their deepest workings has been shown by recent investigations. The ores consist of galena, cerussite, blende, and zinc carbonate, associated with sulphides and carbonates of copper, iron pyrites, and spathic iron ore. Generally speaking, the main portion of the ore bodies consists of galena more or less mixed with blende, while carbonate of zinc occurs partly on the walls and partly as separate deposits. A rare mineral, adamine, a zinc olivenite, appears to be characteristic of the ore deposits of this locality.

The mines of Laurium were worked by the ancients with great skill and perseverance, the ore having been reached by means of numerous vertical and inclined shafts. Adit levels were not employed, as not only was the topography of the country unfavourable to their construction, but the dryness of the mines also rendered them unnecessary. The working of the ancient mines was systematically conducted, the ore having been extracted from the veins by stoping from one level to another, and from the beds by pillar and stall. When the ore was comparatively pure, it was all removed and pillars of dry masonry were substituted, but when the galena was much mixed with blende, forming an intractable mixture for smelting, pillars of veinstone were left standing. In the thicker beds two floors were sometimes established, as is now the practice in working thick coal seams. The extraction of the ore was very complete, as even the metalliferous wall rock was invariably removed. Dry masonry appears to have been exclusively employed in the few cases in which the walls or roof needed support. The tools used were picks, bars, and sledges, but fire-setting does not appear to have been resorted to for disintegrating the rock, which is not well suited for the employment of that process. Traces of the use of tools are constantly met with, and an iron gad found by M. Cordella, although completely oxidized, still retained its shape.

The ore was carried up the inclined shafts, probably in skin sacks, and the water must have been got rid of in the same way. In the inclines, the steps up which the men went are still visible, as well as are numerous niches for lamps, many of which have been found in place. From the circumstance that heaps of vein-stuff, &c. surround the perpendicular shafts, M. Cordella is of opinion that the windlass and pulley were to some extent employed for hoisting. These shafts also served for ventilation, and at the top of some of them a sort of chimney has been found, in which a fire was probably built to increase the natural circulation of air. The deepest shaft mentioned was 395 feet in depth, but none of them reached the sea level. A portion of the ore removed from the mine at this early period was too poor to admit of being economically smelted, and was consequently subjected to a process of concentration. Some of the appliances used for this purpose have been found under the slag heaps in a tolerable state of preservation.

Water was scarce at Laurium, and large reservoirs were built for the purpose of storing a sufficient supply; these were so strongly constructed that they might even now be employed for the purpose for which they were originally designed. The washing apparatus was so planned as to admit of the water being used over again continuously, and consisted of a sluice, some seventy feet long, provided in its length, at intervals, with small reservoirs or wells. Instead of being straight, this sluice formed several angles in such a way that its head and lower end were in close proximity, so that ore, placed at its head, could be washed by water baled or otherwise raised from the well at its lower extremity. In this way a current was established, and the ore washed by a stream of water constantly returning to the wells to be again used.

The ore was smelted in small blast furnaces blown by hand bellows, the fuel being either wood or charcoal. The slags produced contained from 5½ to 14 per cent. of lead. The work lead, which M. Cordella has reason to believe averaged ·4 per cent. of silver, or about 130 oz. per ton, was refined by cupellation. No part of the apparatus used for this purpose has been discovered, but the frequent occurrence of fused masses of desilverized litharge sufficiently proves the nature of the process by which it was obtained. The lead was assayed for silver in the usual way, and earthen cupels, of nearly the same form and dimensions as those now employed, have been found in the waste-heaps.

The period of the greatest activity at the Laurium mines, which, although belonging exclusively to the State, were leased to private individuals, was between 600 B.C. and the Peloponnesian War, a period of about 170 years. M. Cordella estimates the number of workmen employed at this date at 15,000, all of whom, including the foremen and superintendents, were slaves. During the Peloponnesian War, Laurium was cut off from the capital, and the slaves revolted, after which the mines were worked fitfully and upon a reduced scale; operations being sometimes restricted to the re-smelting of the old slags. The mines were also worked to some extent under the Romans, but only through the agency of Greek factors; and in the first century of the Christian era, Laurium was completely abandoned; nor is there any evidence that work was ever recommenced until the year 1864.

The aggregate amount of labour expended by the ancients was enormous; some 2,000 shafts, averaging about 250 feet in depth, have been found, and the extent of the underground workings is in proportion. The quantity of slag originally left was about 2,000,000 tonnes, which M. Cordella calculates must represent 2,100,000 tonnes of lead and 8,400,000 kilogr. of silver, in addition to which the ancient miners left behind them millions of tonnes of halvans in the form of waste-heaps, containing from 1½ to 18 per cent. of lead. The zinc ores were not worked.

Some idea of the general mode of occurrence of the ores will be afforded by the following section, Fig. 70, after Cordella, through the most important deposits of lead ore and calamine at Laurium.

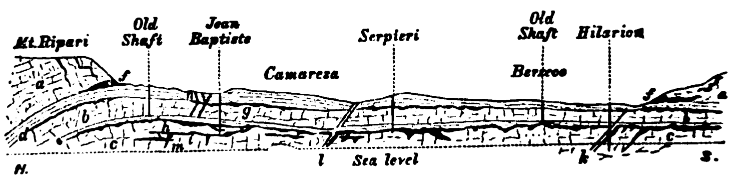

FIG. 70.—Laurium; vertical section.

In the above section, *a* represents a more or less ferruginous limestone; *b*, middle crystalline limestone, in places somewhat siliceous, and impregnated with sulphuretted ores; *c*, lower limestone (marble), which has not yet been sunk through by the new shafts; *d*, middle mica schist of Camaresa, with lenticular interpolations of limestone and quartz, including small lead veins. The thick upper mica schist, not shown in the section, rests on the upper limestone, *a*, of the Ripari Mountain.

A mica schist, *e*, of lesser thickness, which almost always forms the hanging wall of the third contact deposit; *f*, upper ore bed or first contact bed; *g*, second ore bed; *h*, third ore bed, much worked by the ancients; *i*, calamine. This mineral occurs in all horizons, but is most extensively developed in the foot wall of the third contact bed, where, at Camaresa, it is from 3 to 24 feet in thickness, and contains from 42 to 46 per cent. of zinc. Blende sometimes occurs with the calamine.

A granite vein, *k*, courses from east to west, and dips 40° north;

it is more or less weathered, and forms the hanging wall of the first rich calamine deposit discovered by Cordella in 1869. The felsite vein of Camaresa, *l*, is 6 feet in thickness, traverses the entire mass, and contains rich lead ores under the third contact bed. Veins of calamine, *m*, coursing east and west, vary from 8 inches to 4 feet 9 inches in thickness, and dip almost perpendicularly, those in the lower limestone, *c*, being of especial importance. Numerous small lead veins, *n*, were worked by the ancients.

Fig. 71 is a section, also after Cordella, of the Jean Baptiste shaft, 63 fathoms in depth, the mouth of which is 577 feet above sea level. In this section, *d* represents mica schist, 144 feet in thickness, enclosing lead veins, *n*; *o* is an old level about 13

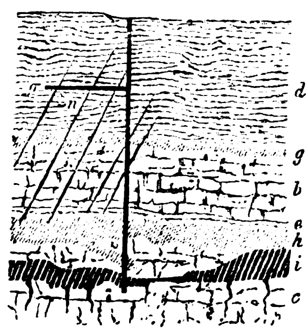

FIG. 71.—Laurium, Jean Baptiste shaft; vertical section.

fathoms from the surface; and *g*, the second contact lead bed, 18 inches thick. The limestone, *b*, is 103 feet in thickness; the mica schist, *e*, 4½ feet thick; and *h*, the third contact lead deposit, 16 feet in thickness.

The calamine bed, *i*, has an average thickness of 11½ feet, and *c* is crystalline limestone.

The most important mining company is the "Société Française des Mines du Laurium." The ores raised are galena and cerussite, very rich in silver, with blende and calamine; the number of miners usually employed is about 2,700.

The calamine of Laurium is richer than that of Sardinia, and is usually calcined previous to exportation. After calcination it contains on an average about 60 per cent. of zinc. The lead ores of Laurium are associated with blende, from which they are separated at ore-dressing works which have been erected for the purpose.

The production of the mines of this company in 1881 was as follows:—

	Tonnes.
Roasted calamine	36,665
Raw calamine	101
Blende	246
Lead ores	1,543
Mixed ores	2,820
Iron ores containing manganese	847
Argentiferous lead	1,722
Total	43,944

Various other mining companies are working in the district, such as the Sunium, the Austro-Belgian, the Pluto Company, the Société d'Olymp Lauriotique, &c., which, although they possess deposits of ore, have not as yet attained a large production.

In the Sunium Mine, first opened in 1873, sixty men are employed, and up to the present time about 1,500 tonnes of zinc ore have been produced. The calamine here occurs irregularly at the surface, in limestone near the sea shore.

There are numerous deposits of similar ores in Greece, among which may be mentioned the irregular mass of zinc ore in limestone at Mount Hymettus, and the argentiferous lead and copper lodes traversing the limestones and mica schists of Karysto. These deposits contain quartz, galena, chalcopyrite, and iron pyrites. The ore worked contains from 15 to 20 per cent. of lead, and from 800 to 1,000 grms. of silver per tonne of lead. Numerous veins of argentiferous lead have also been discovered in the islands of Antiparos, Siphanto, Zea, Anaphi, Milo, and Santorin.

COPPER.—Copper ores have been discovered at different places, sometimes mixed with lead ore, and at others isolated in the state of sulphides and carbonates. At Laurium the lead ore is more or less cupriferous. The ore at the Jean Baptiste shaft sometimes contains from 6 to 12 per cent. of copper. At Karysto the galena contains from 5 to 18 per cent. of copper.

MANGANESE.—The Greek Government has recently granted a large number of concessions for so-called manganese mines; but the majority of them refer to iron ores, containing manganese, and suitable for the manufacture of Bessemer steel. In one of these mines only has pure manganite been found. At Andromonastiri, in Messina, rich manganese ore has been found, forming beds sometimes eighteen inches in thickness, in Cretaceous rocks; while at

Peracbora, in Corinth, a lode of good oxide of manganese has been discovered; and in Milo pure manganese ore has been found, forming irregular masses in trachyte.

CHROMIUM.—Chromite frequently occurs in Greece; but in a very irregular manner; sometimes in the form of impregnations only, and at others in more or less considerable masses enclosed in serpentine. At Vattonde, in Eubœa, considerable quantities of rich chrome ore are worked; the ore occurring in the form of thick veins traversing green serpentine. The ores supplied by the mines of the Eubœa and Skyros are preferred on account of their superior quality.

The limited employment of chromates, and the discovery of rich deposits in Thessaly and Asia Minor, which are worked open-cast, have, however, greatly affected the working of chrome mines in Greece, and the majority of them are now abandoned.

IRON.—Greece is rich in iron ores, and the occurrence of iron slags in various localities shows that the iron ores not utilized at the present day were extensively employed by the ancients. Large masses of such slags have been found at Karysto, Seripho, and in many other places. In the slag-heaps of Seripho, a Carthaginian coin was found dating from the fourth century B.C.; the period at which it may be supposed that this establishment was in operation. The iron ores generally consist of iron carbonate, hæmatite, and magnetite, forming irregular masses in the limestone, or at the contact of the limestone and mica schists. The greater portion of the ores contain manganese, those of Seripho yielding from 5 to 8 per cent. of this metal.

In 1869 a company was formed to work the ores of Seripho, where brown hæmatite was found near the sea shore in the form of contact masses from nine to forty-five feet in thickness. This ore, which contains 50 per cent. of iron and about 4 per cent. of manganese, much resembles the brown hæmatite of Bilbao in Spain. In the interior of the island masses of magnetic iron oxide exist in the immediate vicinity of granite, but have not been worked.

Cordella gives the following as the mineral production of Greece in 1877:—

	Tonnes.	Value.
Zinc ore	31,000	£104,400
Lead ore	860	9,120
Magnesite	1,500	1,800
Manganite	50	240

According to Dr. Gurlt, the present average annual production of Greece is about as follows:—[1]

	Tonnes.
Zinc ore	9,000
Lead ore	1,000
Chromium ore	2,000
Magnesite	1,500

In addition to this, 10,000 tonnes of argentiferous lead are produced annually at Laurium from the old slag heaps.

SPAIN.

Spain takes the lead of all other countries in the amounts of lead and quicksilver which it produces. The copper district of Huelva is one of the most important in the world, and the iron mines of Bilbao are famous both for the quantity and quality of their ores. The chief lead-producing province is Murcia, on the south-eastern coast, which affords two-thirds of the annual yield of the country, while that of Santander, on the Bay of Biscay, leads in the production of zinc ores. The provinces of Santander and Murcia, together, afford nine-tenths of all the zinc ores raised in the country. Nearly the whole of the copper is obtained from the province of Huelva, in the extreme south-west, adjoining the celebrated pyrites district of Portugal; while iron ore is extensively mined in the neighbourhood of Bilbao and in the province of Murcia.

GOLD.—In Spain gold mines were successively worked by the Phœnicians, Romans, and Moors, and although the amount at present obtained is exceedingly small, it is believed that this country formerly yielded large quantities of the precious metal. Strabo and Pliny both mention Spain as a gold-producing country, and name various localities where it was obtained.

M. Piette, who has devoted much attention to the subject of ancient mining in the Peninsula, is of opinion that formerly both Spain and Portugal produced gold, and, further, that it was obtained, not only from washing the sands of valleys and rivers, but also from workings in the solid rock. His investigations, however, led him to the conclusion that if the auriferous regions were originally rich,

[1] Dr. A. Gurlt, *Glaser's Annalen*, 1882, No. 112.

they had become almost totally exhausted previous to their abandonment; since, during the whole of his examinations of the old workings, he met with only a few very slight traces of gold. Among the gold mines of the Peninsula, which have been worked in comparatively modern times, may be mentioned one near Talavera, and another at Domingo Flores, in Leon, which was wrought, intermittently, during a period of nearly a hundred years subsequently to its commencement in 1639.

SILVER.—The silver mines of Gaudalcanal and Cazalla, north of Seville, occur in mica schist, and were formerly very productive, but are now of little or no importance; there were also formerly mines at a short distance from that city, which are said to have yielded large returns during some portion of the seventeenth century. Rich argentiferous galena is found in the Sierra Almagrera, and has been worked to a considerable extent.

The most important silver mines of modern times were, however, those of Hiendelaencina, situated in the province of Guadalajara, seventy miles north-east of Madrid. These mines were discovered near the village of Hiendelaencina in 1843, and shortly afterwards a concession was obtained, and a mine commenced, which, in honour of the patron saint of the village, was called Santa Cecilia. Of the other mines subsequently opened the most remarkable were the Suerte, Fortuna, Verdad de Los Artistas, Relampago, San Carlos, and Vascongada, all of which yielded large amounts of silver. There are numerous other lodes in the district, but only that on which the above mines are situated was worked with advantage. Its direction is nearly east and west, with a dip to the south, and its average thickness is not quite two feet; the enclosing rock is gneiss, associated with mica schists. The gangue is heavy spar, but quartz and spathic iron also occur. The ores are principally argentite, freieslebenite, miargyrite, and ruby silver ore; although galena, antimony glance, native silver, chloride and bromide of silver, are likewise present. The average yield of the ores produced was about 90 oz. per ton.

The mines of Hiendelaencina, which were worked to a depth of 200 fathoms, began to decline in their yield in 1860, and in 1866 the majority of them had already suspended operations. Since that period, we are without any statistics relative to their production; but from the beginning of 1847 to the end of June 1866, the Hiendelaencina mines yielded 8,196,704 oz., Spanish, of silver; equivalent to 7,578,536 oz., English.

LEAD.—Lead is found in all the provinces of Spain with the exception of Valladolid; but the most important deposits of lead ore are those of Jaen, Murcia, and Almeria.

The town of Linares, in the province of Jaen, is situated on a plateau of nearly horizontal sandstone of Triassic age, which has seldom a thickness exceeding thirty-five feet, and which reposes directly upon granite. Both the sandstones and granite are traversed by two distinct systems of lead veins, the more important of which strike either north-east and south-west, or east-north-east and west-south-west; a smaller number, however, of broader and more irregular veins, comparatively barren and coursing east and west, are met with on the slopes of the Sierra Morena north of Linares. The ferruginous quartz, which constitutes the outcrops of the more productive system of veins, frequently forms projecting crests through which are scattered grains of galena, which gradually become more numerous as greater depths are reached. Generally speaking these lodes become productive at an inconsiderable distance from the surface, yielding galena, comparatively poor in silver, associated with blende, iron and copper pyrites, spathic iron ore, cerussite, and calcite, enclosed in a predominantly quartzose gangue. No decrease in the width of the veins had been observed at a depth of 135 fathoms and, as a general rule, they were found to be richer in their broader than in their narrower parts. The ore chimneys or bunches are nearly vertical, and as the lodes often divide into branches and subsequently re-unite, it not unfrequently happens that rich bunches of ore are found at the point of junction with one another. The larger veins, coursing approximately east and west, are composed principally of quartz and heavy spar enclosing iron pyrites, copper pyrites, and galena, poor in silver. The outcrops of these veins sometimes project above the surface of the sandstone to a height of several feet; the ores being usually disseminated in strings instead of being concentrated in chimneys as in the case of the smaller and more productive lodes.

Among the undertakings under English management in this district are the Linares Mines, which yielded, in 1881, 4,312 tons of lead ore, while the mines of the Fortuna and Alamillos Companies produced respectively 4,344 tons and 3,533 tons during the same period.

The Sierra de Cartagena[1] is composed of Silurian slates and limestones penetrated by trachytes and basalts, and surrounded at the base by rocks of Tertiary age. Both the Silurian rocks and

[1] F. de Botella, "Descripcion geologica-minera de las provincias de Murcia y Albacete," Madrid, 1868.

the trachytes in the vicinity of Almazarron, some distance west of Cartagena, are traversed by a number of veins of which the direction approximates closely either to north and south or to east and west, and of which the dip is usually almost vertical. In the stratified rocks the ores occur partly in fissure veins, and partly in strings or branches parallel to the bedding; they also form lenticular or bedded veins, which are sometimes of considerable extent and thickness. These deposits often enclose fragments both of slate and trachyte, and must consequently be more recent than the latter rock. They are usually composed of an irregular mixture of ferruginous silica with galena, iron and copper pyrites, mispickel, magnetite, calcite, heavy spar, and quartz.

The broader parts of these veins are, for the most part, comparatively barren, while the narrower portions and the branches are often almost exclusively composed of various metallic sulphides. Two other forms of lead deposit occur in the province of Murcia; the one forming impregnations of galena, pyrites, and blende, in a compact greenish rock, while the other occurs in the form of beds, or bedded veins, in limestone.

The Sierra Almagrera rises in the north-eastern portion of the province of Almeria, forming a range of about 1,000 feet in height and fifteen miles in length, on the coast of the Mediterranean. Although it rises somewhat abruptly towards the south-east, the slope in the contrary direction, towards the plains, is extremely gradual. It consists chiefly of mica schist, passing into clay slate, and is frequently intersected by deep gorges, and traversed by numerous veins, the most remarkable of which is the Jaroso Lode, named after one of the neighbouring ravines. This lode, towards the north, splits into numerous branches, while to the south it is cut off by a fault. The portion which has been worked between these two points is about 2,100 feet in length. The strike of this vein is almost due north and south, with an average dip of 60° east; its greatest width is twenty feet, and it frequently includes fragments of the country rock. Heavy spar, spathic iron ore, calc spar, red and brown iron ore, argentiferous galena, and iron and copper pyrites form the filling of the fissure. This lode is distinguished for the combed arrangement of its constituents, and for the number and beauty of its crystallized minerals. The vein material to a depth of eighteen fathoms consisted, for the most part, of decomposed clay slate, hæmatite, limonite, and heavy spar; beneath this followed the most productive horizon containing rich argentiferous galena, with occasionally cerargyrite, associated with iron ores. Below the depth of eighty-two fathoms the proportion of silver began rapidly to decrease, while heavy spar and hornstone became predominant. B. v. Cotta suggests that the presence of very rich ores below the depth of eighteen fathoms, may possibly be accounted for on the hypothesis that the metals washed out of the gossans had become concentrated in this zone.

Although the combed structure of this lode is very remarkable, the arrangement of the several layers is by no means symmetrical, and it follows that they cannot have been the result of successive deposits on the sides of a single fissure. It may therefore be concluded that the vein has been repeatedly fissured, and that the re-filling of these rents has resulted in the want of symmetry observed. This becomes the more probable from the circumstance that, in the middle of the lode, horses occur which at a certain period of its formation appear to have formed the wall of an adjoining comb.

The importance of lead mining in Spain will be understood when it is stated that in 1881 that country produced 320,898 tonnes of lead ore, and that out of 59,905 persons who obtained their living by mining 18,969 were employed in lead mines.

ZINC.—The Cantabrian coast of Spain is rich in calamine, more especially the provinces of Guipuzcoa and Santander. At La Nestosa, Comillas, &c., deposits of this ore occur in dolomitic limestone of Jurassic age, partly in the form of veins, and partly as very irregular deposits, containing, principally, calamine and galena. The calamine is chiefly carbonate of zinc, although zinc silicate and snow-white zinc bloom are also of frequent occurrence. The ores are often embedded in clay, and the centre of large blocks is sometimes formed of dolomite, thus indicating the origin of the ore. At greater depths crystallized blende of a bright brown colour is found in concretionary masses, covered by concentric layers of heavy spar, or, near the surface, partly converted into zinc carbonate. Calamine was first discovered in the north of Spain in 1852, and in 1862 considerable attention had become directed to this region by the large and increasing quantity of zinc ores which were being sent into the market.

The zinc deposits in the provinces of Santander and Madrid are very fully described by W. K. Sullivan and J. P. O'Reilly.[1] These gentlemen conclude that the zinc carbonate, and perhaps also the lead carbonate, was originally precipitated from solution either by

[1] "Notes on the Geology and Mineralogy of the Spanish provinces of Santander and Madrid," London, 1863.

carbonate of lime or by dolomite. In some instances the replacement is so complete that calamine passes insensibly into pure dolomite, as at the Venta Mines, and still more strikingly at the Vicenta and Reocin Mines. Both the carbonates of calcium and magnesium appear to have taken part in the decomposition; but the magnesium carbonate, as the more soluble, appears to have been wholly removed, while some of the carbonate of calcium still remains filling joints, or forming a kind of conglomerate.

COPPER.—A zone of clay slate, 110 miles in length, courses in a north-westerly direction through the provinces of Huelva in Spain, and of Alemtejo in Portugal, and encloses enormous deposits of cupriferous iron pyrites.

In Spain the deposits of Rio Tinto and Tharsis are the most important. The age of the enclosing rocks is somewhat doubtful, many geologists believing them to be of either Silurian or Devonian age. F. Römer[1] is of opinion that they belong to a low horizon of the Culm-measures.

Near the ore deposits, and parallel to them, dykes of quartz-porphyry often occur, and Spanish geologists have suggested a connexion between the two; this, however, Römer does not feel inclined to accept. These deposits of cupriferous pyrites consist of a series of more or less continuous lenticular masses running parallel with the bedding of the enclosing slate, sometimes extending to a great length, occasionally having a width exceeding fifty fathoms, and composed of an intimate admixture of iron pyrites with a little copper pyrites, through which strings of the latter mineral sometimes ramify. Small strings of black sulphide of copper less frequently traverse the mass.

At Rio Tinto the deposits of cupriferous pyrites assume the form represented in Fig. 72. The slate, which stands nearly vertical, is altered in the immediate vicinity of the deposits by the action of the acid salts resulting from the decomposition of pyrites, and not only becomes softer but also assumes a yellowish-white or reddish-grey tint. This decomposition of pyrites proceeds with considerable activity, and it has been calculated that, since the mines were abandoned by the Romans, from 70,000 to 80,000 English tons of metallic copper must have been carried into the sea by the Tinto River.

The compact or finely crystalline pyrites, which frequently exhibits a stratification parallel to that of the country rock and exhibits similar joints and headings, contains, on an average, about

[1] F. Römer, *Zeitschr. d. d. geol. Gesellsch.* 1876, p. 354.

2½ per cent. of copper. Quartz, galena, blende, and arsenical pyrites occur very subordinately, and drusy cavities are exceedingly rare. These deposits have, almost without exception, been wrought at a very early date, the workings having, in some cases, reached a depth of above fifty fathoms. These ancient excavations, the larger proportion of which are undoubtedly Roman, were confined to the branches of richer ore before referred to, which not only traverse the main deposit, but also sometimes extend into the quartz-porphyry forming one of the walls.

The Roman workings consist of numerous circular shafts, which are seldom more than thirty inches in diameter, in connexion with various tortuous galleries, which invariably follow the richer branches of ore. By becoming saturated with waters holding copper salts in solution, the ancient woodwork of the mines has been wonderfully preserved, while its tissues have sometimes

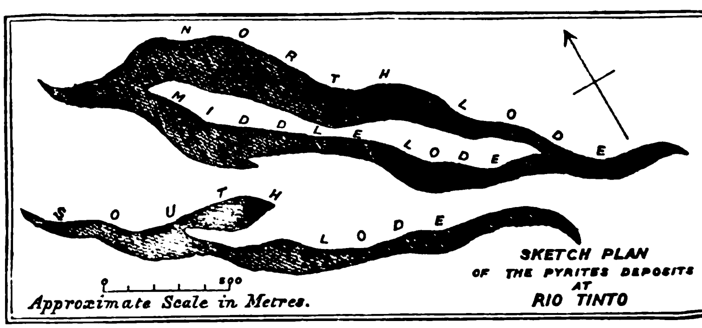

FIG. 72.—Pyrites deposits, Rio Tinto.

become permeated with metallic copper, resulting from the reduction of its salts by woody fibre. In this way timber which has been employed for supporting the ground, is often so perfectly preserved as to retain markings and letters cut by Roman miners eighteen centuries ago.

The drainage was, in Roman times, effected by a series of wooden wheels with buckets, acting somewhat in the manner of the eastern *noria*, of which numerous remains have been discovered. Earthenware lamps of Roman workmanship are constantly found in the old workings, while implements and vessels of bronze have been occasionally met with. Still less frequently human bones have been discovered, which, by the action of copper salts upon their calcic phosphate, have assumed an appearance resembling that of turquoise. It may be here mentioned that some years since a bronze plate was found at the entrance of a Roman gallery at Rio Tinto, recording the fact that it was commenced during the reign of Nerva, A.D. 96-98.

Up to the present time Rio Tinto has been extensively worked in open-cast, the ores being in part exported, and in part treated locally for the copper they contain by a process of solution and precipitation. The very extensive scale upon which operations are conducted at Rio Tinto will be gathered from the following figures. The amounts of pyrites which were produced during three recent years were as follows:—

	For Shipment.	For Local Treatment.	Total.
In 1880 . . .	277,590 Tons[1] . . .	637,567 Tons . . .	915,157 Tons
1881 . . .	249,098 ,, . . .	743,949 ,, . . .	993,047 ,,
1882 . . .	259,924 ,, . . .	688,307 ,, . . .	948,231 ,,

The average copper contents of the entire quantity raised in 1882 was 2·805 per cent., and for the previous year 2·75 per cent.

The amount of the Company's pyrites consumed in England, Germany, &c., during the same year was 272,826 tons, against 274,201 in 1880, and 256,821 in 1881.

The copper produced during the year 1882 by treatment at the mines was estimated at 10,822 tonnes of 1,000 kilogr., and there were actually brought to market 9,740 tons of 21 cwts., leaving the balance to be carried forward to the next year.

The following are the quantities of metallic copper produced at the mines yearly for seven years, namely:—

In 1876, 976 tons of 21 cwts. net.		In 1879, 7,179 tons of 21 cwts. net.
1877, 2,495 ,, ,, ,,		1880, 8,559 ,, ,, ,,
1878, 4,184 ,, ,, ,,		1881, 9,466 ,, ,, ,,
		1882, 9,740 ,, ,, ,,

Exclusive, in each case, of copper contained in the pyrites exported.

In addition to copper, Spanish and Portuguese pyrites contains from 20 to 35 dwt. of silver per ton, together with traces of gold, both of which were, for many years, not utilized. These metals are now, however, recovered by the Claudet process, and in 1883 no less than 348,210 oz. of silver and 1,911 oz. of gold, which would otherwise have been lost, were thus obtained.

The Tharsis and Calañas deposits, both lying west of Rio Tinto, belong to the Tharsis Sulphur and Copper Company, and possess so close a general resemblance to those of the last-named locality as to require no special description. The total amount of pyrites

[1] English tons.

extracted from the Tharsis and Calañas Mines during the year 1882 amounted to 486,860 tons, and shipment was made of 212,218 tons of pyrites and 5,534 tons of copper precipitate.

QUICKSILVER.—Mining for quicksilver was carried on at Almaden, in New Castile, at a very early period. Theophrastus speaks of the stony cinnabar of Spain, and Vitruvius mentions that cinnabar was found in that country and brought thence to Rome for treatment. Strabo states that this mineral was found in Turdetania (Almaden), and Pliny informs us that 10,000 lbs. weight of it was annually sent to Rome.

The quicksilver deposits of Almaden occur in Upper Silurian slates, which are sometimes interstratified with beds of limestone, but the slates themselves, which are much contorted, rarely contain cinnabar. The wall rock usually consists of black carbonaceous slates and quartzites, alternating with schists and fine-grained sandstones.

The deposits of cinnabar strike east and west, incline, near the surface, at an angle of about 65°, and then dip almost vertically. There are three deposits, of which the most important are the San Francisco and the San Nicolas, each of which has an average thickness of above 20 feet. They are sometimes divided from one another by only two or three feet of soft slate, and at the 135-fathom level are worked as one, the width of the common opening being 67½ feet. These deposits consist principally of quartz, with either granular or compact cinnabar, which permeates the mass generally, or is besides concentrated in pockets and bunches, while the clefts and cavities, by which the deposit is traversed, often contain native mercury. At times geodes of calc spar are enclosed in the ore, which likewise contains iron pyrites and occasionally a little galena. In the year 1830 cinnabar in a stalactitic form was found in the Concepcion Nueva Mine, at Almadenejos; this, which was compact and of a yellowish-red colour, was probably a recent formation.

There has been much difference of opinion with regard to the nature of these deposits. Casiano de Prado,[1] who was for many years director of the works, states that they exactly follow the strike and dip of the Silurian rocks, and he therefore calls them beds, but remarks that veins of cinnabar occur also to a subordinate extent in the immediate neighbourhood. He, however, considers it probable that the ores may have penetrated the slates from below; in that case they could scarcely be regarded as true

[1] Don Casiano de Prado, "Minas de Almaden," Madrid, 1846.

beds. A. v. Groddeck classes them with bedded deposits, as does also Nöggerath, who studied the district in 1860 and 1861.[1] Hoppensack,[2] Willkomm,[3] and Le Play,[4] on the other hand, have regarded these deposits as lodes. The last-named author considers the vein-like character to be very evident, as he observed distinct quartz selvages separating the vein on both sides from the country rock. He also found in the so-called lodes fragments of a diorite which occurs in the immediate neighbourhood, and with the eruption of which he believes them to be intimately connected.

The richest ore obtained contains 25 per cent. of mercury, the average production of the whole of the ore treated being 8·3 per cent. The average production of quicksilver at Almaden during the last ten years has been 36,000 flasks, weighing 1,242 tonnes. In 1876 seventeen mines yielded 26,323 tonnes of quicksilver ore, and, in 1877, 26,765 tonnes of ore were produced from eighteen mines.[5] In 1882 13 mines, employing 3,240 miners, afforded 27,037 tonnes of ore, worth £39,633.

TIN.—The Phœnicians are believed to have procured tin from Spain, and to have carried it to various ports on the Mediterranean At the commencement of the Christian era the price of this metal was equal to about five shillings per pound, and it was consequently regarded as very valuable.

In Spain tin occurs both in veins and disseminated in alluvial gravels, and is most frequently found in the provinces of Orense and Pontevedra, where, within an area of twelve square miles, about thirty different lodes have at various times been worked since 1830. These veins, which seldom exceed seven inches in width, traverse mica schists and hornblendic rocks. The veinstone consists of quartz with a little mica, through which tin ore, wolfram, and iron pyrites are sparingly disseminated. In the province of Salamanca there are, traversing the older slates, quartz lodes which contain tin ore, and in 1875 the tin mines of that region afforded employment to seventy workmen.[6] Near Cartagena tin ore occurs in lenticular deposits in Permian slate.[7] Tin ore has also been found in the province of Almeria.[8]

[1] A. Nöggerath, *Zeitschr. Berg. Hütt. Salinenw.* vol. x. 1862, p. 361.
[2] J. M. Hoppensack, "Ueber den Bergbau in Spanien überhaupt und den Quecksilberbergbau zu Almaden insbesondere," Weimar, 1796.
[3] M. Willkomm, "Die Quecksilbergwerke zu Almaden," *Polytechn. Centralblatt*, 1849, p. 357. [4] M. F. Le Play, *Annales des Mines*, vol. v. 1834, p. 175.
[5] *Revista Minera*, 1883, p. 647.
[6] Massaret, *Ann. Soc. Geol. Belg.* 1875, ii. p. 58.
[7] M. Garcia, *Boletin de la Comision del Mapa Geológico de España*, vol. iii. 1876, p. 2
[8] *Revista Minera*, 1821, p. 148. B. v. Cotta, "Die Lehre von den Erzlagerstätten," 1861, vol. ii. p. 457. E. Reyer, "Zinn." 1881, p. 154.

In 1880 one mine only was productive, employing four miners and yielding about 12 cwts. of black tin.

IRON.—The value of the Biscayan deposits of iron ores has been long appreciated, but it is only within recent years that their development has assumed such enormous proportions. The most important of these deposits are situated on the left bank of the River Nervion, above the town of Bilbao,[1] and range, approximately, south-east and north-west, the rocks associated with them belonging to the Cretaceous period.

Commencing from the river, and taking them in order from south-east to north-west, they may be separated into the seven following groups:—

Ollargan, Iturrigorri	Brown ores, much mixed with clay.
Castrejana	Brown ores.
Matamoros	Brown ores in large deposits.
El Regato	Brown ore (not worked at present).
Triano and Somorrostro	Red and brown ores (these are the main deposits).
Galdames	Brown ore.

Official returns show that the output of these mines in 1881 was 2,800,075 tonnes.

To this the various groups contributed in the following proportions:—

	Tonnes.
21 mines in Ollargan, Iturrigorri, and Castrejana	84,128
4 „ „ Matamoros	568,149
38 „ „ Triano and Somorrostro	2,031,055
2 „ „ Galdames	116,743
Total	2,800,075

Of this quantity, Matamoros, Triano, and Somorrostro raised 2,599,204 tonnes; or about 93 per cent. of the whole.

The ores found in these deposits are known locally as:—*Campanil*, red hæmatite; *Rubio*, brown hæmatite; *Vena dulce*, a soft rich ore, common to both deposits; and *Carbonato de hierro*, spathic iron ore. The spathic iron ore has not yet been exported.

[1] W. Gill, *Journal of the Iron and Steel Inst.* 1882, p. 63.

The *Campanil* has hitherto been found under workable conditions only at Triano and Somorrostro, and forms but a small proportion of the whole; but as this mineral is most in request it is disappearing more rapidly than the brown ore. It is slightly inferior to the *Rubio* in percentage of iron, but its freedom from silica renders it specially valuable.

The *Rubio* is a hard brown ore, and, when of good quality, is richer in metallic iron than the *Campanil;* but from its association with siliceous matter, and, occasionally, with pyrites, it requires careful selection. It also contains more moisture than the other ores. The *Rubio* deposits are sometimes very deceptive, and what appear to be mountains of ore turn out to be merely shells of good mineral, with poor siliceous material beneath.

The *Vena dulce* is soft, of a deep purple colour, very rich in iron, and has been worked for centuries, by means of galleries and other underground excavations. This ore is seldom wrought separately excepting in small quantities for special purposes, or for treatment in Catalan forges, or by the Chenot process.

The *Carbonato de hierro,* spathic iron ore, occurs in both red and brown ore mines, but the most extensive deposits of it yet found are in the latter, where it underlies the *Rubio.*

In the classification given above, the term *Vena* includes other and harder forms of this ore, known locally as *Vena acampanilada, Vena rubiada* or *Rubio avenado,* according as it partakes of the nature of *Campanil* or *Rubio* respectively. The relation of these ores to one another, together with their order of succession, has not been thoroughly investigated; no geological survey has been attempted, and no deep borings have been made. There seems to be no absolute rule as to the relative positions of the *Rubio* and the *Vena;* in some mines the latter will underlie the former, the ore growing purer as it descends. Both orders of position are observable in the Matamoros district. Certain of the rugged escarpments of *Rubio,* which form such remarkable features of the brown ore mines, have probably been at one time covered with *Vena;* which, being the softer ore, has been washed out. The two ores are often, but not invariably, separated by beds of clay.

The little that is known of the geology of the district has been gathered from the studies of M. Colette in 1845, and of Don Ramon de Adan y Yarza in 1877. Some notes upon the nature and formation of the ore deposits have also been published, in 1878 and 1879, by M. Bourson and M. Baillis. The investigation has, however, only been partial, and the inferences drawn have not been entirely confirmed by subsequent experience.

The accompanying analyses give the average composition of the ore raised in the Orconera Company's mines.

	Red Ore.	Brown Ore.	
Ferric oxide	78·03	79·96	78·29
Alumina	·21	1·44	1·15
Manganous oxide	·86	·70	·74
Lime	3·61	1·00	·50
Magnesia	1·65	·55	·02
Silica	5·91	8·10	8·80
Sulphuric acid	·01	·10	·05
Sulphur	trace	·05	·04
Phosphoric acid	·03	·03	·02
Carbonic acid	5·00		
Combined water	4·60	8·25	10·55
	99·91	100·18	100·16
Metallic Iron	54·62	55·97	54·80

The average number of miners employed in the Bilbao mines is about 7,000.

Although the iron mines of the province of Biscay are by far the most productive in Spain, ores of this metal are somewhat extensively mined in various other localities. At the Juanteniente Mine, in the vicinity of El Pédroso,[1] a small town situated 28 miles north-east of Seville, in the Sierra Morena, a vertical deposit of specular iron ore, varying from thirteen to sixteen feet in thickness, has been worked in mica schist; this may be followed for a distance of 328 fathoms in the direction of its strike, the thickness remaining nearly the same throughout. The iron ore, which is a finely granular specular ore, passing into compact red iron ore, is sharply defined against the country rock, and is occasionally traversed by small strings of quartz, or rendered impure by enclosures of iron pyrites. Several similar beds occur in the same vicinity, as at the Rosalina and Monte Agudo Mines.

In the year 1880, 3,565,338 tonnes of iron ore were produced in Spain from 774 iron mines, employing 14,795 workmen. The exports during the same period were 2,932,998 tonnes of iron ore, and 3,766 tonnes of pig iron.

[1] F. Römer, *Zeitschr. d. d. geol. Gesellsch.* vol. xxvii. 1875, p. 63.

Oxide of manganese, of which about 5,000 tonnes are annually produced in Spain, is found in irregular pockets presenting no peculiar features.

GENERAL SUMMARY OF THE PRODUCTION OF METALLIFEROUS MINERALS IN SPAIN DURING THE YEAR 1882.[1]

Description of Ore.	Quantities.	Values.	
	Tonnes.	Pesetas.	£
Iron ore	4,726,293	11,767,004	470,680
Lead ore	341,818	44,949,117	1,797,964
,, argentiferous	22,425	4,876,971	195,078
Silver ore	18,349	1,779,154	71,166
Gold ore	360	9,000	360
Copper ore	1,720,853	18,897,598	755,904
,, argentiferous	50	50,000	2,000
Tin ore	0·23	250	10
Zinc ore	57,353	1,928,810	77,152
Quicksilver ore . . .	27,037	990,841	39,633
Antimony ore	30	6,450	258
Cobalt ore	40	26,170	1,046
Manganese ore . . .	5,668	227,897	9,115
Total value of Metalliferous Minerals produced in 1882		85,509,262	£3,420,366

PORTUGAL.

Almost all the known geological formations are found in Portugal. One third of its area consists of igneous rocks, a second third is composed of the more ancient sedimentary deposits, and, finally, Tertiary and alluvial deposits occupy large areas near the centre of the country, besides being less plentifully disseminated in other parts of the kingdom.

Although these various formations contain important deposits of valuable ores, the literature of the subject is extremely scanty, being, according to M. F. d'Albuquerque d'Orey,[2] the author of a valuable memoir on the mineral resources of Portugal, confined to the catalogues of the Paris Exhibition of 1867, and of the Philadelphia Exhibition of 1876. For the purposes of this memoir the author referred to availed himself of certain official MSS. in the Government Mining Bureau, to which, with the exception of

[1] "Estadistica Minera de España correspondiente al Año 1882," *Revista Minera*, 1883, p. 647.

[2] "Die Bergwerks Industrie in Portugal," *Berg. und Hüttenm. Zeit.* 1881, p. 201, etc.

what relates to the mines of San Domingos, I am indebted for the figures quoted.

Many of the more important ore deposits of Portugal were worked successively by the Phœnicians, Carthaginians, and Romans, but the circumstance that until the early part of the present century all minerals were regarded as national property, the ownership being vested in the Government, tended to materially retard the progress of this branch of industry. In 1852, however, the mining laws were revised and reformed, and from that year recent mining in Portugal may be said to date.

Gold is found in small quantities in the sands of some of the rivers, but the amount collected is so insignificant as to be of no commercial importance.

There are no deposits in Portugal of silver ores proper, but this metal occurs to a small extent in association with ores of lead and copper.

LEAD, ZINC, AND ANTIMONY.—Lead occurs in various localities, the deposits, to some extent, resembling those of Spain. The principal lead districts are those of Villa Real, Vizeu, Aveiro, Portalegre, and Beja. The most important lead-mining area is apparently that of Mertola, near the Guadiana, where the galena contains about 24 oz. of silver per ton, while the cerussite and anglesite, &c., which accompany it are sometimes much richer. Zinc ores are not known to occur in Portugal in workable quantities, but blendes so argentiferous as to be classed as silver ores have sometimes been found. Ores of antimony, chiefly in the form of sulphides, occur in three different regions, and occupy as many distinct geological formations.

In the district of Evora, antimony ore occurs in a quartz lode at the contact of Palæozoic beds and granite.

The principal antimony veins in the neighbourhoods of Valongo, Paredes, and Gondomar in the district of Oporto, may be divided into two systems characterized by different strikes. The deposits coursing N. 10° to 20° W., may be described as bed-like lodes, since their strike is identical with that of the country rock. The other system courses N. 30° to 60° E., and both occur in Silurian rocks. A third region of antimonial ores is situated near the town of Alcoutim, in the district of Faro, where there are two distinct lodes, one coursing east and west and the other north-west. The latter has the same strike as the country rock, and is the only one now worked. These lodes occur in the slates of the

Culm formation, and their production was formerly greater than it is at the present time.

COPPER.—Numerous copper veins occur in granites and porphyries in the district of Evora, and another important deposit is that of Palhal, in Aveiro, which, in addition to copper, contains small quantities of nickel and cobalt. The most important copper deposits are, however, those of San Domingos, Aljustrel, and Grándola, enclosed in the great metalliferous belt extending into Portugal from the Spanish province of Huelva.

The celebrated mine of San Domingos, which produces the principal portion of the cupriferous pyrites raised in the country, is situated in an arid and rocky district nine miles from the Guadiana River and about thirty miles from the sea. The lithological characteristics of this part of the country are almost identical with those of the metalliferous district of Huelva in Spain, and the ore deposits, of which the strike is west-north-west and east-south-east, are probably of the same age. The ore, which is a cupriferous iron pyrites, yields, by dry assay, about 2¼ per cent. of copper, but contains less arsenic and somewhat less silver than some of the Spanish ores.

San Domingos, like Rio Tinto and Tharsis, was extensively worked by the Romans, who, from the coins which have been found in the various excavations, appear to have occupied this locality from the latter portion of the reign of Augustus down to the partition of the Empire under Theodosius, a period of about three and a half centuries.

In the valley into which the drainage level empties itself, rows of sarcophagi, still containing bones, have at various times been found, while in other excavations, cinerary urns and other indications of cremation have been repeatedly met with.

Among the relics which have been found of ancient mining operations, the most interesting was a series of large drainage wheels of wood in a state of perfect preservation. These wheels, to the number of ten, were furnished with buckets on their circumference for the removal of water; eight of them being sixteen feet in diameter, while the other two had a diameter of twelve feet only.

The quantity of pyrites extracted from this mine from the date of its being first opened to the end of 1877, has been approximately as follows:—

Ancient excavations estimated at 150,000 cubic metres; modern excavations 659,671 cubic metres. Total 809,671 cubic metres, or about 3,578,745 English tons.

During the year 1882 the output of pyrites from San Domingos amounted to 405,029 tons, in addition to which about 5,000 tons of copper were obtained in the form of precipitate from the local treatment of the ores.

Copper ore deposits likewise occur in the province of Algarve, at the contact of Jurassic and Triassic rocks, where they are traversed by dykes of diorite and serpentine. These deposits, which contain magnetite, in their geological and mineralogical characters somewhat resemble the deposits of Traversella, and of Monte Catini in Tuscany. They, however, contain comparatively little copper, and the mines once opened upon them are now abandoned.

TIN.[1]—Tin ore occurs in Portugal in various localities, especially in the provinces of Beira, Minho, and Tras-os-Montes, where it is found in alluvial gravels, in the form of stockworks in the granite, and as tin veins in the older slates. Tin mines were worked in Portugal in the time of Agricola, and tin-streaming, on a small scale, is one of the oldest industries of the country.

Eschwege[2] found tin ore in the sands, as well as in the granites, of Valongo, and established stream-works with considerable success; but the unsettled state of the country is said to have ultimately brought the enterprise to a standstill.

There are no available statistics relative to the present annual yield of tin ore, but the value of the yearly production has been estimated at £450. In 1874 tin mines were worked in the province of Tras-os-Montes to the depth of about twenty-five fathoms, but were ultimately abandoned as unremunerative.

IRON.—Portugal is rich in iron ores of good quality, large and important beds of this mineral occurring in almost all parts of the kingdom; however, with but few exceptions, all the iron mines of the country are now abandoned. The exportation of a few thousand tons of iron ore to England represents the whole of the production of the mines of Portugal. This is accounted for by the poverty of the country in coal, and by the absence of forests, resulting from the extravagance of former generations.

Among the iron ore deposits of Portugal the following are the most important, namely:—the hæmatite bed of Quadramil, in the province of Tras-os-Montes, which may be followed for a distance of five miles. It is frequently sixty-six feet in thickness, and occurs in Laurentian rocks. The iron ore veins in the Braganza district, Tras-os-Montes, now produce less than 200 tons of ore

[1] E. Reyer, "Zinn," 1881, p. 155.
[2] *Karsten's Archiv*, 1835, p. 221.

per annum. The iron ore deposits of Moncorvo, also in the same province, consist of a number of lenticular ore beds, coursing north 70° in Laurentian rocks. These beds have a gentle dip, are frequently traversed by quartz veins, and are sometimes as much as 328 feet in thickness. They contain both red iron ore and magnetite; and large masses of ore which have become detached from the outcrops by former rains, have formed, in the valleys, extensive surface deposits which have been estimated at ten million tons. The iron ore in the beds themselves is estimated at least at fifteen million tons, and contains from 39 to 59 per cent. of iron.

In the district of Odemira, in Alemtejo, iron and manganese deposits occur as lodes, as surface deposits, and as deposits of sandstones containing iron. The lodes, which traverse Laurentian limestones and slates, are very wide, and contain hæmatite, pyrolusite, heavy spar, and quartz. The production of this district attained its maximum in 1874, when 40,496 tons of iron ore were produced, and from that date to 1877 has rapidly decreased, the present output being exceedingly small.

MANGANESE.—In Portugal ores of manganese frequently occur in association with iron ores, but there are also deposits containing manganese ores only. These are principally found in the province of Alemtejo, where they occur in a zone about twenty-four miles in length between the towns of Mertola and Grandola, parallel to which are the celebrated pyrites deposits of Rio Tinto, Tharsis, and San Domingos. Manganese ores here form lenticular beds coursing N. 40° W., in Silurian and Lower Carboniferous strata, and are usually accompanied by beds of quartzite; manganese ores also occur in the form of lodes traversing quartzites. The ore is pyrolusite, and with it occur red hæmatite and heavy spar, while the country rock, as before stated, is quartzite. In 1875 twelve mines were working in this district, and the Paço Mine alone produced 812 tons of ore, and employed sixty workmen. No official returns are made of the metalliferous minerals annually produced in Portugal.

SCANDINAVIA.

Scandinavia is to a large extent composed of the older crystalline rocks, such as granite, gneiss, mica schist, chlorite schist, talc schist, hornblende schist, crystalline limestone, dolomite, &c.; which are frequently traversed by porphyries, gabbros, basalts, and other igneous rocks. Overlying these rocks are strata of Silurian and Devonian age, which in some districts cover considerable areas, but the more recent sedimentary rocks are represented only in the most southern portion of Sweden. True veins are not of frequent occurrence among the ore deposits of Scandinavia, since the majority of them are either bedded veins, or are associated with bed-like masses called *Fahlbands*. Iron and copper ores are the most important, after which come silver and cobalt ores; and then, very subordinately, lead, zinc, and nickel ores.

NORWAY.

The fundamental rocks of Norway are assigned by Norwegian geologists to the Azoic epoch, in which are included the Archæan rocks,[1] as well as the earlier gneiss. The close of the Archæan period in Norway was marked by eruptions of granite, which in some cases form extensive ranges of hills, while in others they constitute irregular detached masses. These granites are frequently accompanied by gabbros, and appear to have exercised an important influence upon deposits of ore. Immediately after the great changes produced by the eruptions of granite, and possibly even while they were still in progress, the deposition of beds of Taconic age commenced.[2] These beds, of which there are three, rest unconformably on the older rocks. The second member of the series has been identified as corresponding to the Potsdam sandstone of the United States. The Taconic beds cover a large proportion of the area of Norway. The Silurian and Devonian formations occur mainly in two considerable areas, the one at and north of Christiania, and the other near the most southern limits of the country.

Four outbursts of plutonic rock are recognised as having taken place in Norway; namely, a Pre-Taconic, a Post-Taconic, a Silurian, and an eruption of Post-Devonian age. Throughout Southern Norway the formations from the Devonian to the Post-Tertiary are entirely wanting.

SILVER.—The celebrated silver mines of Kongsberg,[3] which

[1] O. G. Broch, "Le Royaume de Norvège et le Peuple Norvégien," p. 106.

[2] Taconic, a term applied by Professor Emmons to certain rocks east of the Hudson, which consist of slates, quartz rock, and limestone, of Lower Silurian or Upper Cambrian age.

[3] *Karsten's Archiv*, xxi. 1847, p. 242; A. Gurlt, *Berg. und Hüttenm. Zeit.* 1858, p. 101; T. Scheerer, *Ibid.* 1866, p. 250; P. Herter, *Zeitschr. d. d. geol. Gesellsch.* 1871, vol. xxiii. p. 383; G. v. Rath, *Neues Jahrb. f. Mineral.* 1869, p. 434; O. Weltz, *Berg. und Hüttenm. Zeit.* 1878, p. 115.

were first opened in 1623, are situated in a district consisting chiefly of gneiss, gabbro, mica schist, hornblende schist, talc schist, and chlorite schist. The ore occurs in association with fahlbands, but as these have been already described, p. 102, no further description of them is necessary. The most remarkable fahlbands near Kongsberg are at the Overberg, five miles in length, on which are some very ancient mines; and on the plateau of Underberg, where some of the workings are 300 fathoms in depth. Several fahlbands occur west of the Overberg, and there is a small one at Helgevand. The origin of these is explained by Kjerulf and Dahll on the hypothesis of the formation of fissures through the eruption of gabbro, and the impregnation of the rocks by metallic sulphides.

At Kongsberg there is a marked distinction between fahlbands in slate and those in gabbro, the former only being important. The maximum amount of impregnation occurs in mica schists, and the minimum in quartzite slates. Böbert, who was the first to recognise fahlbands as a distinct form of ore deposit, shows their transition into the lenticular ore beds characteristic of crystalline schists. The Kongsberg fahlbands are comparatively poor and contain, quite subordinately, compact segregations which are never worth working. To the miner, however, they are of great importance, since the silver lodes are only productive of ore within the fahlbands. Near the town of Kongsberg there are about fifty old mines, of which, approximately, one quarter may have been sunk to a depth of 130 fathoms, the others being generally much shallower. All these mines were formerly worked for silver, and some of them are still working for that metal, which occurs partly as native silver, and partly in the form of various sulphides. The Kongsberg silver mines are the property of the State, those now in operation being the Kongens og Armen, the Gottes Hülfe in der Noth, and the Haus Sachsen. The latter, after lying unworked for many years, was re-opened in 1866. The Kongens og Armen Mine yielded for a long period the chief portion of the silver produced in Norway, and has, at the deepest point, now reached a depth of 306 fathoms, of which 131 fathoms are beneath the adit level. The Gottes Hülfe is 131 fathoms in depth, and of the material brought to the surface about 60 per cent. is classified as productive work.

From the Kongens og Armen Mine the average annual production during the five years from 1871 to 1875 was 4,446 cubic yards of rough ore, which yielded about 3,670 oz. troy of native silver, 141 tonnes of rich ore, and 1,468 tonnes of poor ore.

At the Gottes Hülfe Mine the average annual production during the same period was 1,715 cubic yards of rough ore, affording 835 oz. of metallic silver, 14 tonnes of rich ore, and 511½ tonnes of poor ore. The native silver averaged 880 fine, the percentage of silver in the rich ore being 1·85, and in the poor ore ·054. During the year 1879 the Kongsberg silver mines yielded the following returns:—[1]

The Kongens og Armen Mine produced 2,577 kilogr. of native silver containing 88 per cent. silver, and 670 tonnes of silver ore containing ·28 per cent. silver, worth, respectively, 309,200 kroner, or £17,177, and 248,100 kroner, or £13,783.

The Gottes Hülfe Mine produced 81 kilog. native silver, and 44·374 tonnes of silver ore, worth, respectively, £544 and £944.

The Haus Sachsen Mine produced 37 kilog. native silver and 52·264 tonnes of silver ore, worth, respectively, £245 and £1,528. This gives a total for Kongsberg of 770 tonnes, worth £34,222.

In 1879 the only other mine in Norway producing silver was the Svenningdals[2] Mine in Vefsen. This produced 105 tonnes of silver ore containing about 1 per cent. of silver, worth £6,111.

Auriferous quartz has recently been discovered in Norway, but whether the gold is present in sufficient amounts to be remunerative has not yet been determined.

COPPER.—The ore masses of Røros and Dovre, near Trondhjem,[3] which are enclosed in Lower Cambrian mica schists, chloritic schists, and clay slates, are always conformable with the strata, and never occur as true veins. The mineralogical character of these deposits is simple, the principal ores being iron pyrites, copper pyrites, magnetic pyrites, and sometimes, at the outcrop, magnetite. Blende and galena are occasionally met with, but otherwise the beds and the slates in which they occur are poor in minerals. The beds may be divided into two classes, the first containing iron pyrites, and the second copper pyrites and magnetic pyrites. Copper pyrites is intimately mixed with the iron pyrites, but the mixture of copper and magnetic pyrites is always distinct. The iron pyrites crystallizes in cubes, and contains as much as 5 per cent. of copper; in the copper pyrites and magnetite beds this percentage is somewhat greater, while in the Storvarts Mine, at Røros, the copper reaches 7 per cent. The magnetic pyrites contains ·2 per cent. of nickel and cobalt, and the iron pyrites ·25 per cent. of these metals.

[1] "Tabeller Vedkommende Norges Bergværksdrift," 1882, p. 16.
[2] *Ibid.*
[3] A. Helland, "Forekomster af kise i visse skifere i Norge," Christiania, 1873.

The beds, although always conformable, are extremely irregular, so that they sometimes represent short masses, with but little extension either in the direction of their strike or dip. Their thickness is variable, the thickest mass of pyrites being probably that in the abandoned mine of Løkkens, namely eighty-five feet. Thicknesses of from thirty-three to forty-two feet are sometimes found at Ytterøen, Foldal, and Undal, but this great depth is exceptional, the average not being above from three to eighteen inches. At Foldal the extent in the direction of the strike is 312 fathoms, and in the Storvarts Mine 191 fathoms. The Røros beds, which are nearly horizontal, have been followed in the direction of their dip for about 710 fathoms. The pyrites beds usually disappear by thinning out, but they sometimes become divided before disappearing. These beds are found in certain slates only, and are absent in all the other formations. In the province of Trondhjem, in Søndfjord and in Sondhørdland, there are non-fossiliferous slates which are remarkably rich in pyrites. This pyritiferous formation frequently lies immediately above the Azoic rocks.

In the large pyrites deposits at Ytterøen slate seams alternate with pyrites; and in the middle of the pyrites bed at Undal there is a stratum of alum slate, with a strike and dip coinciding with that of the pyrites. It is remarkable that some of the beds containing pyrites are of a black colour, from being mixed with a certain proportion of carbon; thus the pyrites from Stordøen contains 2·6 per cent. of that substance. It is well known that pyrites sometimes replaces organic forms, so that these beds may possibly have been deposited through the instrumentality of organisms.

The yield of Røros during the year 1879 was as follows:—

The Storvarts Mine produced 2,380 tonnes of copper ore, containing 7 per cent. of copper; the Ny-Solskin Mine 380 tonnes, containing 6·3 to 8 per cent. of copper; the Kongens and Arvedals Mines 1,920 tonnes, containing from 3·2 to 3·6 per cent. of copper; and the Gammel-Solskin Mine 510 tonnes copper ore; giving a total for the Røros district of 6,880 tonnes copper ore, worth £17,770 and 4,550 tonnes cupriferous iron pyrites, containing 43 per cent. sulphur, worth £3,185.[1]

The Varalso Mine, which is worked upon a bedded vein enclosed in the slates of the island of the same name, has, during the last sixteen years, afforded an average yield of 9,000 tons of pyrites annually. This ore contains less than 1 per cent. of copper, but is almost entirely free from arsenic.

[1] "Tabeller Vedkommende Norges Bergværksdrift," 1882, p. 19.

The Ytterø Mine, in Ytterøen, produced, in 1879, 409 tonnes cupriferous iron pyrites, and 6 tonnes of copper ore, worth £315.

In 1879 the Vigsnæs Mine, near Stavanger, produced 39,898 tonnes of cupriferous iron pyrites, worth £69,500.

The ore district of Tellemarken begins two geographical miles from Kongsberg, and extends sixty-five miles to the west and south-west, and forty-eight miles to the north, of that town.

The rocks of the district consist of quartzites, quartzite slates, hornblende schists, &c., and these are penetrated by granite and are traversed by granitic veins; in some places these granite veins contain copper ores. Scheerer[1] describes granite veins at Strömsheien on a table-land about 3,300 feet above the sea, between Moland, in Tellemarken, and Valle, in Sädersdalen which, although occurring in gneiss, have the greatest similarity to the veins in the slates of Tellemarken.

These granite veins, which are of variable thickness, namely from 16 to 25 feet, consist of a granite very rich in quartz but poor in mica, containing, as accessories, magnetite, garnet, apatite, beryl, and various other minerals. They contain copper glance in nests and ramifications, in such a way that Scheerer was led to suppose that the ore and granite were introduced at the same time by igneous fusion. The copper ores enclosed within the granite of Tellemarken are mixed with quartz, and of this he describes two characteristic examples, namely; a vein at the Moberg Mine, from three to thirteen feet in thickness, and almost vertical, consisting half of granite and half of quartz, containing copper ores, with tellurium-bismuth; and a thick granite vein at the Näsmark Mine, traversed by regular vein fissures running obliquely across it, filled with quartz, copper glance, and variegated copper ore.

Fig. 73, after Scheerer, is a section of this vein, in which *a* represents mica schist, *b* granite, and *c* veins of quartz containing copper ores.

Herter[2] thinks it certain that the quartz and copper ores were subsequently deposited in fissures in the granite vein, and there can be but little doubt that the copper ores and quartz filling these fissures are the result of segregation from the granite, in the same way that the gold quartz of the Australian *mullock veins* is the result of the decomposition of an eruptive rock. With an increase of depth all the copper lodes of Tellemarken have gradually ceased to be worth working.

[1] *Berg. und Huttenm. Zeit.* 1863, p. 157.
[2] *Zeitschr. d. d. geol. Gesellsch.* vol. xxiii. 1871, p. 377.

A thick mass of diorite, coursing from north to south, continuous for many miles, and traversing both crystalline slates and grauwacke, contains at Kaafjord, in latitude 69° north, various copper lodes. These course from south-west to north-east, are from one foot to fourteen feet in thickness, and are filled with a breccia of quartz, calc spar, iron pyrites, and copper pyrites, which are cemented together by altered diorite.

The Kaafjord Mine produced, in 1878, 2,700 tonnes of copper ore, worth £6,555, and employed fifty-five men. In 1879 this mine was not working.[1]

NICKEL.[2]—The nickel deposits of Ringerikes occur in fahlbands. Their production in 1876 was 9,320 tonnes of nickel ore, containing 1·5 per cent. of nickel, worth 375,000 kroner, or £20,833. In 1879 it only amounted to 420 tonnes, worth £777. Two other mines produced nickel ore in 1879, namely; Bamble, 300 tonnes, worth £770; and the Senjen Mine, 3,828 tonnes, worth £5,000.

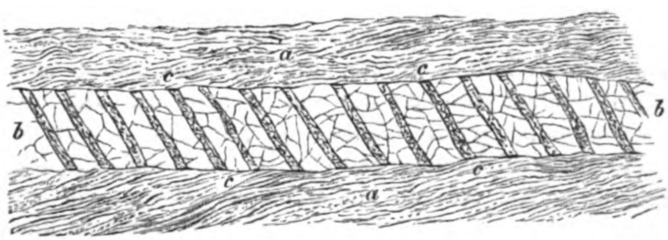

FIG. 73.—Vein at the Näsmark Mine; horizontal section.

A nickel mine, formerly of great importance, is that of Espedalen, near the town of Lillehammer. The district is composed of gabbro and amphibolite, both possessing a gneissic structure and containing, in fahlband-like zones, nickeliferous magnetic pyrites yielding from 2 to 3 per cent. of nickel, with nickeliferous iron pyrites containing about 2·1 per cent. of nickel with a little copper.

The production in 1876 was 2,250 tonnes of nickel ore, worth £4,722, but since that year no ores have been raised at this mine.

The production of nickel ores in Norway has of late years fallen off considerably; in 1876 the total yield was 42,550 tonnes, containing 332 tonnes of metallic nickel, worth £143,333; in 1879 it was only 4,548 tonnes, containing 46 tonnes of metallic nickel, value £15,861.

COBALT.—The cobaltiferous fahlbands of the district lying around Skutterud and Snarum, occur in crystalline rocks varying

[1] "Tabeller Vedkommende Norges Bergværksdrift," 1882, p. 19.
[2] T. Scheerer, *Berg. und Hüttenm. Zeit.* 1845, p. 801.

in character between gneiss and mica schist, but, from the presence of hornblende, they sometimes pass into hornblende schists; among the accessory minerals are garnet, tourmaline, and graphite. These schists, of which the strike is north and south, and which have an almost perpendicular dip, contain fahlbands very similar in character to those of Kongsberg. They differ from those of that locality, however, inasmuch as while, here, the fahlbands are often sufficiently impregnated with ore to pay for working, those of Kongsberg, although to some extent containing disseminated sulphides, are only of importance as zones of enrichment for ores occurring in veins. The ore zones usually follow the strike and dip of the surrounding rocks, and vary in breadth from 2½ to 6 fathoms. The distribution of the ores is by no means equal, since richer and poorer layers have received special names and are easily recognised. The *Erzbänder*, or ore bands, are distinguished from the *Reicherzbänder*, or rich ore bands; while the bands of unproductive rock are known as *Felsbänder*. The predominant rock of the fahlbands is a quartzose granular mica schist, which gradually passes into quartzite, ordinary mica schist, or gneiss. The ores worked are cobalt glance, arsenical and ordinary pyrites containing cobalt, skutterudite, magnetic iron pyrites, copper pyrites, molybdenite, and galena. It is remarkable that in these mines nickel ores do not accompany the ores of cobalt in any appreciable quantity. The principal fahlband is known to extend for a distance of about six miles, and is bounded on the east by a mass of diorite which protrudes into the fahlband, while extending from the diorite are small dykes or branches traversing it in a zigzag course. It is also intersected by dykes of coarse-grained granite which contain no ore, but which penetrate the diorite.

The Skutterud Mine in 1879 produced 7,700 tonnes of cobalt ore, which yielded 108 tonnes of cobalt schlich, containing from 10 to 11 per cent. of cobalt, and worth about £11,000.

IRON.—The rocks in the vicinity of Arendal[1] are gneiss and various crystalline schists, which enclose beds of limestone, and often pass over into mica schist or hornblende schist. These rocks strike north-east and south-west, dip at a considerable angle south-west, and enclose numerous deposits of magnetite more or less mixed with specular iron ore, in a belt sixteen miles in length, parallel with the coast, and extending from Oyestad to Flackstad.

The ore masses are of a lenticular form, vary from 6 to 60 feet in thickness and from 250 to 600 feet in length, and are

[1] T. Kjerulf and Tellef Dahll, *Neues Jahrb. f. Min.* 1862, pp. 557-581.

surrounded by a peculiar envelope, consisting of a mixture of the constituents of the metalliferous bed and of the country rock; the principal minerals being mica, hornblende, epidote, garnet, calcite, and magnetite. The centre of the bed usually consists of magnetite, which is sometimes coarsely granular, but is always accompanied by augite, hornblende, garnet, calcite, and the constituents of gneiss, as well as by various other minerals. These, when crystallized, have rounded faces, a peculiarity frequent with crystals formed in granular limestone. A somewhat foliated texture parallel to that of the enclosing rock, and representing the longitudinal extension of the lenticular masses, is often to be remarked. A great variety of minerals are found in the fissures which traverse the ore bed; among these may be mentioned stilbite, datolite, prehnite, fluor spar, &c. Granitic veins, containing many rare minerals, traverse equally the ore bed and the country rock. The different beds have very different forms, and do not all contain the same minerals, so that each exhibits distinct individual peculiarities.

Haussmann states that these deposits, as well as the enclosing rocks, are traversed by three distinct vein formations, namely: by veins whose composition is similar to that of the ore deposit; by veins composed of felspar and calc spar, containing titanite; and, lastly, by veins of coarsely granular granite.

No returns were made for Arendal in 1879, and in that year the production of iron ore in Norway was confined to the Naes og Egelands Mines, and the Fensgruberne in Holden, producing, respectively, 2,400 tonnes, and 5,660 tonnes, of iron ore, worth £1,055 and £2,500; employing in the aggregate thirty-eight miners.

GENERAL SUMMARY OF THE PRODUCTION OF METALLIFEROUS MINERALS IN NORWAY DURING THE YEAR 1879.[1]

Description of Ore.	Quantities.	Values.	
	Tonnes	Kroner.	£
Silver ore	875	726,000	40,334
Iron ore	8,060	64,000	3,556
Copper ore	10,469	640,000	35,556
Cupriferous iron pyrites .	50,318	1,395,700	77,539
Nickel ore	4,548	118,000	6,556
Cobalt ore	108	200,000	11,112
Zinc and lead ore	9	300	17
Total value of Metalliferous minerals produced in 1879		3,144,000	£174,670

[1] From "Tabeller Vedkommende Norges Bergværksdrift," Christiania, 1882.

SWEDEN.

A large portion of the surface of Sweden is composed of crystalline rocks, such as granite, gneiss, porphyry, &c., and in these the most important metalliferous deposits have been discovered. The crystalline Primary rocks are, generally speaking, immediately covered by beds of Quaternary age, and a very small portion only of the intermediate formations are represented. Of these, rocks of Silurian age occupy the largest area.

LEAD AND SILVER.—The argentiferous lead ores of Sala occur in irregular veins, coursing through granular limestone, and are more or less mixed with such minerals as calcite, chlorite, talc, sahlite, epidote, and actinolite. They are also associated with layers of hälleflinta and serpentine, while quartz, heavy spar, and some other minerals are occasionally present. The galena is usually accompanied by other metallic sulphides, such as iron pyrites, magnetic pyrites, blende, geocronite, boulangerite, and, more rarely, with stibnite, mispickel, &c. The silver usually occurs as sulphide in the form of argentiferous galena, and but rarely either in the native state or in combination with other metallic elements, although specimens of native amalgam are known to have been found at Sala about two hundred years ago. As the deposits are not separated from the enclosing rocks by well-defined walls, the ores are often disseminated through the surrounding limestone, or infiltrated into its fissures to a distance of several fathoms from the more concentrated masses. This sometimes takes place at one side, and sometimes on the other, but occasionally on both sides of the vein. The disseminated ore gradually decreases in quantity as a greater distance from the main deposit is reached, until it at length becomes too poor for working, and gradually passes into a pure limestone entirely destitute of ore. The old mine of Sala is remarkable as having been wrought to the depth of 165 fathoms almost entirely without the use of gunpowder, the primitive method of fire-setting being continued to the present time.

Similar deposits are found at Löfas in Dalecarlia, and Guldmedshyttan in Westmanland, where lead ores occur in granular limestones belonging to the crystalline slates. The production of lead and silver ore at Sala during the ten years from 1870 to 1879 inclusive, was 83,853 tonnes, or an average of 8,385 tonnes per annum.[1]

[1] *Jernkontorets Annaler*, 1883, p. 32.

The Löfas Mine, which is fifty fathoms in depth, produced, from 1870 to 1879, 729 tonnes of silver lead ore, giving an annual average of 73 tonnes.

ZINC.—The most important zinc mine in Sweden is that of Åmmeberg,[1] which lies between the great lakes Wener and Wetter, and belongs to the famous Belgian company La Vieille Montagne. Here a remarkable deposit of blende occurs in granitic gneiss, forming a belt 250 fathoms in thickness, which can be followed for a distance of nearly two miles along its strike. This zone is composed of a gneiss consisting of a mixture of grey felspar and quartz, with but little mica. The enclosed deposit of blende has a very varying thickness, dips at angles of from 70° to 80°, and consists of a number of lenticular masses which sometimes attain a thickness exceeding twelve fathoms. In many places blende can be seen to replace the mica of the gneiss, but geodes of ore never occur in these deposits. The blende, which is black to yellowish in colour, is rarely accompanied by galena, but more frequently by iron pyrites and magnetic pyrites. The other minerals found with the zinc ore are amazonstone, hornblende, talc, chlorite, garnet, black tourmaline, and bitumen; calc spar is rare, and neither magnetite, magnetic pyrites, nor iron pyrites beds accompany the blende.

The present depth of this mine is 58 fathoms, and, during the period 1870 to 1879 inclusive, it produced 341,524 tonnes of zinc ore, and 14,439 tonnes of argentiferous galena; an average, respectively, of 34,152 tonnes of zinc ore, and 1,444 tonnes of lead ore, per annum.[2]

COPPER.—The well-known copper ore deposit of Falun[3] has been generally described as a segregation on account of its large dimensions, and is probably to be regarded as a bedded deposit. The ores are associated with a massive stratum of a grey splintery quartz, which is enclosed in mica schist rich in quartz; the schist is interstratified in the gneiss. In the quartz bed small quantities of the alkalies and a little alumina have been found, and it has therefore been sometimes regarded as a variety of hälleflinta.

The so-called concretions form lenticular masses generally running parallel to the stratification, and in a bed which contains enclosures of magnetite and pyrites are lenticular masses of ore sometimes attaining a thickness of above thirty feet, and

[1] F. M. Stapff, *Berg. und Hüttenm. Zeit.* 1861, p. 252. B. Turley, *Ibid.* 1866, p. 405.
[2] *Jernkontorets Annaler*, 1883, p. 32.
[3] F. M. Stapff, *Berg. und Hüttenm. Zeit.* 1861, p. 195.

continuing for a distance of 100 feet along their line of strike. These masses consist principally of iron pyrites, magnetic pyrites, and copper pyrites. Thin laminæ of chlorite and quartz are frequently enclosed in the mass; but blende and galena are somewhat rare. The ore masses have no well-defined boundaries, but pass over gradually into the country rock. The quartz bed is intersected in various directions by irregular bands of talcose or chloritic rocks, which the miners call *skölar;* these enclose fine crystals of magnetite, gahnite, garnet, falunite, &c. Irregular pyritic lenticules are enclosed in the *skölar,* their principal mass consisting of finely granular iron pyrites and copper pyrites with, in places, blende and galena. Besides ore and *skölar* the quartz bed contains diabase and limestone. *Hårdmalm* (hard ore) is the name given by the Falun miners to the ore consisting of pyrites with quartz; the richest in copper and the purest variety of ore. Where the country rock is impregnated with ore the mineral from such impregnations bears the name *tvikmalm* (doubtful ore), because from mere inspection the miners are unable to determine whether it can be worked at a profit. Ores consisting of pure pyrites are termed *blötmalm* (soft ore), and are very similar to those of the Rammelsberg, but are generally more crystalline. *Segmalm* (tough ore) is a mixture of pyrites with talc, chlorite, and black mica. The proportion of copper in the pyrites treated varies from 1 to 2 per cent., and in the "hard ore" from 3 to 4 per cent. Professor Eggertz found traces of gold in the Falun copper, but was unable to discover from which particular variety of ore it was derived. This mine, which is 194 fathoms in depth, yielded, during the ten years immediately preceding 1880, an average of 24,438 tonnes of cupriferous pyrites, and 1,181 tonnes of iron pyrites, annually.[1]

At Tunaberg the ore occurs in a bed of granular limestone in grey gneiss. The limestone contains, principally, hornblende, mica, serpentine, lead, silver, copper, and cobalt ores; copper pyrites and cobalt glance being the most frequent.

This mine is 98 fathoms in depth, and during the last ten years has annually produced about 286 tonnes of copper ore.[2]

The fahlbands of Åreskuttan, in Jämtland, are wrought for copper pyrites. The Loos Mine, on the road from Falun to Åreskuttan, is worked on masses of amphibolite, which are enclosed in mica schists and quartz beds. The amphibolite contains enclosures of erubescite, copper pyrites, iron pyrites, blende, speiss cobalt, cobalt pyrites, nickel glance, quartz, calc spar, and anorthite.

[1] *Jernkontorets Annaler,* 1883, p. 30. [2] *Ibid.* p. 32.

IRON.—At Dannemora, in Upland, north of Upsala, coarsely foliated gneiss encloses a broad zone of hälleflinta with chloritic schist, granular limestone, and interstratified beds of magnetic iron ore. The latter have the characteristic lenticular shape, and form a great segregated deposit, which has been worked along the outcrop for a distance of more than a mile. This deposit is in the middle above 180 feet in thickness, but gradually decreases on both sides. The ore, which contains manganese, is a very finely granular magnetite, mixed with particles of chlorite, together with a little calc spar and brown spar. Bands of chloritic slate, *skölar*, up to twelve feet in thickness, traverse the ore deposits. The purest magnetite occupies the middle of the deposit, while near the edges iron pyrites, copper pyrites, blende, galena, arsenical pyrites, quartz, garnet, asbestos, heavy spar, anthracite, &c., occur.

This mine is 110 fathoms in depth, and during the last ten years has annually produced about 35,300 tonnes of iron ore.[1]

At Taberg, near Jönköping in Småland, the mountain rises about 400 feet above the surrounding gneiss. Opinions have considerably differed with regard to the character of this deposit, but A. Sjögren,[2] who has examined a number of sections under the microscope, finds that the entire mountain consists of a granular crystalline mixture of magnetite and olivine with some plagioclase, mica, and apatite, as accessory constituents; but pyroxene and hornblende are entirely absent. The olivine is very fresh, being only exceptionally serpentinized.

The average annual production of iron ore at Taberg during the last ten years has been about 8,250 tonnes.

The beds worked in Wermland in the neighbourhoods of Philippstadt, Nordmark, Långbanbytta, Pajsberg, &c., are very rich in ore. The beds of Pajsberg are enclosed in crystalline granular dolomites from 20 to 100 fathoms in thickness; these dolomites contain granular concretions of hausmannite.[3] The beds, which are from 6 to 18 feet in thickness, and are continuous for about thirty fathoms along their strike, consist of magnetite, specular iron ore, and hausmannite, together with pyrochroite, tephroite, chondroarsenite, heavy spar, diallogite, asphaltum, garnet, chlorite, serpentine, &c.

The island of Utö, a few miles south of Stockholm, consists largely of a highly felspathic gneiss, which is traversed by

[1] *Jernkontorets Annaler*, 1883, p. 32.
[2] *Jahrb. f. Min.* 1876, p. 434.
[3] L. J. Igelström, *Berg. und Hüttenm. Zeit.* 1866, p. 21.

numerous veins of granite. The iron ore deposit, which is embedded in the gneiss and its associated mica slates, hornblende slates, hälleflintas, and granular limestones, is sometimes as much as 125 feet in thickness, and consists of a mixture of specular iron ore magnetic iron ore, and quartz. These minerals are accompanied by iron pyrites, magnetic pyrites, arsenical pyrites, galena, and chalcocite, together with native silver. Granitic veins, containing cassiterite with tourmaline, lepidolite, petalite, &c., traverse the bed, in the fissures of which crystals of calc spar, apophyllite, and quartz, are found. The depth of the workings is 120 fathoms, and the average annual output of iron ore about 10,300 tonnes.

The iron ore deposits of the mountain of Gellivara,[1] in Luleå-Lappmark, are exceedingly rich, but, on account of their geographical position, latitude 67° 20′ N., are not practically very important. The beds attain a thickness varying from 60 to 125 feet, and may be traced for a distance of nearly four miles along their strike. They occur in red gneiss, and consist of a mixture of specular iron ore and magnetite, containing hornblende and quartz; more rarely apatite, calc spar, and corundum.

Lake ores[2] are found in many of the Scandinavian lakes, most frequently in Småland, Southern Oestergötland, North-western Dalarne, in Herjeådalen, in parts of Jämtland, in the whole of Norrland, and more rarely in Helsingland, Gästrikland, Southern Dalarne, and Wermland. In some provinces, however, as in Upland, Södermanland, Westergötland, &c., they are entirely absent. Abundance of fuel and the absence of other ore, is the chief reason why in some provinces these ores have been better investigated and more extensively worked than in others. The districts richest in such ores have a sandy soil, and are more or less covered by forests and peat bogs. Stapff is of opinion that lake iron ore is formed in the same way as bog iron ore, and he points out that in the lake of Tisken, near Falun, the water from the mine and from the slag heaps has deposited a bed of ochre extending over the entire bottom of the lake within a period of about 600 years; this bed is in places above ten feet in thickness. Lake ores when first collected are blackish-grey, brownish, or greenish ochre-like slimes; on hardening, however, little globular masses analogous to those of oolitic iron ores are often formed.

[1] *Jernkontorets Annaler*, 1883, p. 32. B. Turley, *Berg. und Hüttenm. Zeit.* 1863, p. 348.

[2] F. M. Stapff, *Zeit. d. d. geol. Gesellsch.* vol. xviii. 1866, p. 86.

Ehrenberg (1836) first suggested that these ores are produced by certain infusoria, which build cells mainly composed of hydrated oxide of iron. The *Gallionella ferruginea* is especially an industrious manufacturer of iron ore by secretion from dilute iron solutions. The greater or lesser solubility of iron does not entirely depend on the amount of organic or other acids present in the water, but is also influenced by the mineralogical composition of the ferruginous materials from which it is derived. Felspars rich in potash are more slowly decomposed by acids than those containing soda or lime. Amphibolites, diorites, diabases, gabbros, and "bastites," containing iron pyrites, copper pyrites, magnetic pyrites, magnetite and titaniferous iron ore, as accessory constituents, are of frequent occurrence throughout Småland.

Lake ores are not found at a greater depth than about thirty feet, and are rarely nearer to the shore than from thirty to forty feet. The thickness of the beds of lake ore rarely exceeds eighteen inches, but they are sometimes worked when only from four to six inches thick. Experience shows that such a stratum can be renewed in from fifteen to thirty years.

During ten years, 1870 to 1879, the average annual production of metalliferous minerals in Sweden was as follows :—[1]

	Tonnes.
Iron ore { mine	748,427
Iron ore { lake and bog	8,872
Copper ore	40,638
Zinc ore	34,718
Silver and lead ore	11,010
Nickel ore	4,319
Iron pyrites	1,517
Manganese ore	538
Cobalt ore	153
Total	850,192

The production of iron ore in Sweden has considerably increased during the last few years. In 1881 iron ore was raised in thirteen of the twenty-four provinces, with a total output of 806,000 tonnes. The largest amount of iron ore was produced in the province of Örebro, whose 262 mines furnished 220,000 tonnes ; next comes Kopparberg, with 181 mines, yielding 210,000 tonnes, and Westmanland, producing 170,000 tonnes from fifty-seven mines.[2]

[1] *Jernkontorets Annaler*, 1883, p. 32.
[2] *Iron*, 1883, vol. xxi. p. 414.

THE RUSSIAN EMPIRE.

European Russia consists of an immense expanse of plain, flanked by the mountain ranges of the Timan, the Ural, and the Caucasus, almost entirely composed of sedimentary rocks, which are frequently covered by thick alluvial deposits.

Great regularity predominates in the structure of these formations, ore deposits occurring only in areas occupied by the older rocks, as in the district of Olonetz, St. Petersburg, and in the south of Russia. Devonian rocks form a large basin in Central Russia, and in Poland contain deposits of copper. Iron ore occurs in the Carboniferous rocks of Poland, and copper ore is found at various places in rocks of Permian age. The Triassic rocks of Poland are analogous to those of Upper Silesia and, like them, contain deposits of calamine, galena, and iron ore.

The principal metals produced in Russia are gold, platinum, silver, copper, lead, zinc, and iron; tin, nickel, and cobalt also occur in very subordinate quantities. The chief sources of the more valuable metals are the mountain chains of the Ural and the Altai, particularly the former. Copper is found not only in those regions, but also in the Caucasus, in Finland, and in the Kirghese region. Iron occurs abundantly in the Ural Mountains, in portions of the Altai, and in some of the southern and central points of the empire, also in Poland, Finland, and the north. The zinc deposits of Poland are now among the most productive in Europe.

Mining had not assumed an important position among the industries of Russia until about the year 1700, from which period until the reign of Elizabeth its development progressed very rapidly. Towards the latter half of the last century, however, a depression commenced in this class of industry, which, after extending over several years, has of late shown marked indications of improvement.[1]

URAL MOUNTAINS.—From a geological point of view the western and eastern declivities of the Ural chain differ very considerably. The western slopes are formed by hills parallel to the principal axis of the chain, gradually lowering towards the plains. These hills are composed of sedimentary rocks in which, especially near the principal axis of the range, are enclosed masses of granite, diabase, and diorite; in proportion as these disappear the beds

[1] "Aperçu des Richesses Minérales de la Russie d'Europe publié par le Département des Mines du Ministère du Domaine de l'État," Paris, 1878; C. Skalkowsky, "Tableaux Statistiques de l'Industrie des Mines en Russie en 1868–1876;" J. D. Hague, "Mining Industries," 1878, p. 247.

become less disturbed, and gradually attain exceptional regularity as they approach the lowlands of the west.

The eastern side of the range is entirely different, becoming, at a relatively small distance from the axis, flat and uniform, the mountain sides being formed almost entirely of plutonic rocks enclosing imbedded fragments of sedimentary strata. Faults and slides are of frequent occurrence both in the mountains and in the flat country as far as the eruptive rocks extend.

A geological map of the western slope of the Ural exhibits Silurian, Devonian, Carboniferous, and Permian rocks, arranged as more or less parallel bands. On the eastern side of the chain the rocks also exhibit parallel bands, but they are very much contorted and confused. An area of Permian rocks, of considerable thickness and extent, overlies the Carboniferous strata of the western slope, while on the eastern side Carboniferous, or still older, strata are overlain by Tertiary or Post-Tertiary rocks extending over the immense steppes of Siberia. Cretaceous strata occur in the southern portion of the chain, while a large number of quartz veins, some of which contain gold, are met with in the south-eastern slope.

The gold of the Ural Mountains occurs under two distinct conditions, namely, in original deposits, and in detrital beds of auriferous sands. In original deposits the gold may either be enclosed in quartzose veins, or be disseminated in such rocks as diorites, serpentines, &c. Beds of auriferous sands may be deposited either near the original sources of the gold, or have been transported by the action of water and accumulated at a considerable distance from them.

Deposits of gold enclosed in solid rock are worked in the district of Beresovsk in the southern Ural, and in the districts of Werkh-Issetsk, Newiansk, and Goroblagodatsk. Other deposits which, like the above, principally occur in Asia, were formerly worked.

The Beresovsk veins are especially interesting on account of the influence exercised upon them by the country rock. In this locality the crystalline schists are traversed by dykes of finely granular granite, and it is only in the vicinity of these that the quartz veins are found productive. The granite near the auriferous veins is impregnated with iron pyrites which has become partially converted into brown iron ore; this variety of granite has received the name of "beresite." The average yield of the quartz veins which have been worked is thirteen grammes, or about eight pennyweights, to the tonne. The gold is accompanied by iron pyrites, galena, grey copper, plumosite, brown hæmatite, crocoisite, pyromorphite, vauquelinite, bismuth ochre, and native silver. A large number of gold deposits belonging to this class doubtless exist in the Ural, but a relatively small number only have been worked.

In auriferous sands the gold occurs in fine particles which can rarely be detected by the naked eye. These sands are accumulated in beds varying from the thinnest layer to above twelve feet; their ordinary thickness is, however, between eighteen inches and three feet. Their extent is as variable as their thickness, but their length rarely exceeds 1,500 feet. The auriferous bed of Balbouk is, however, about two miles in length, while the longitudinal extent of another deposit exceeds three and a half miles. The width of such accumulations is sometimes very small, but, generally speaking, varies between 60 and 300 feet. The auriferous detritus of the Ural is usually found either in valleys or the beds of streams or rivers, and, besides yielding gold in the form of dust or fine grains, sometimes furnishes nuggets of considerable size; the largest of which, weighing 1,158 troy ounces, was found in the district of Miask. The rocks underlying these deposits are of various kinds, including granite, gneiss, beresite, augite-porphyry, serpentine, chlorite schist, talc schist, clay slate, limestone, &c., and wherever a depression occurs in the surface of the bed-rock the proportion of gold increases. These beds, which are mainly composed of gravel, sand, and clay, associated with water-worn fragments of various rocks, contain, in addition to native gold, platinum, iridium, palladium, iridosmine, titaniferous iron ore, iron pyrites, garnet, zircon, diamond, and many other minerals. Wherever magnetic iron occurs to any large extent the percentage of gold in the sand almost invariably becomes greater. The age of these alluvial beds is comparatively recent, since remains of *Elephas primigenius* and *Rhinoceros tichorhinus* have at various times been found in them.

Vein mining is still carried on in the Ural, although upon a somewhat limited scale, the district of Beresovsk, in which veins of gold-bearing quartz have long been worked, being still the principal centre for this class of mining.

It appears, from official returns relating to the placers of the Ural Mountains, that 5,300 kilogr. of gold, equivalent to 170,400 oz. troy, were obtained in 1875 from 4,240,000 tonnes of auriferous sand; which corresponds to about twenty grains of gold per tonne of material washed.

Almost the whole of the gold produced in the Russian Empire is obtained by placer mining; the total yield from the year 1753, when gold washing was first commenced, to the end of 1876, amounted to 31,427,681 oz., of the approximate value of £128,000,000.

The annual production of gold in Russia from the beginning of 1867 to the end of 1877 is given in the following table:—

Year.	Number of Workings	Quantity of Sand and Material washed.		Quantity of Gold extracted.		Approximate Value of Product.
		Poods.	Tons.	Poods.	Oz.	£
1867	878	968,423,325	15,607,179	1,650	868,656	3,648,355
1868	993	1,177,288,244	18,973,261	1,711	900,768	3,783,225
1869	1,129	1,054,570,392	16,995,531	2,007	1,056,591	4,437,682
1870	1,208	983,475,095	15,849,754	2,157	1,135,560	4,769,352
1871	978	1,081,518,424	17,429,828	2,400	1,263,500	5,306,700
1872	1,055	1,044,027,585	16,825,623	2,331	1,227,172	5,154,122
1873	1,018	954,648,764	15,385,187	2,025	1,066,070	4,477,494
1874	1,035	937,578,045	15,110,074	2,027	1,067,120	4,481,904
1875	1,092	1,007,293,492	16,233,613	1,996	1,050,802	4,413,368
1876	1,130	1,022,543,362	16,479,381	2,054	1,081,339	4,541,623
1877	—	—	—	2,430	1,279,293	5,373,030

Of the above amounts Siberia furnished from two-thirds to three-fourths, the remainder coming from the districts of Perm and Orenburg in European Russia, supplemented by small contributions from Finland and the district of the Kirghese.

Important concessions on the part of the Government have, within the last few years, conferred additional advantage upon private mine owners, and, under these new conditions, out of the 2,430 poods of gold produced in 1877 no less than 2,275 came from private undertakings, and only 15 poods from the mines of the Crown and State.

Platinum usually accompanies gold in the auriferous sands of the Ural, and is not often met with otherwise than in association with that metal; it has, however, in some few cases, been found without any accompanying gold, as in the placers of Taguilsk, Goroblagodatsk, and Bisersk. It has never been found in any considerable quantities in its matrix *in situ*, although small grains of platinum are said to have been occasionally observed in the auriferous quartz of the Beresovsk mines. The entire production of this metal is obtained from placer washings belonging to private individuals, situated in the northern portion of the Government of Perm. At Taguilsk and Bisersk, where the deposits yield platinum usually unaccompanied by gold, the bed and edges of the platiniferous area are described as being formed of serpentine and peridotite, fragments of which predominate among the rocks occurring in the sand. Among the materials forming the deposit are also fragments of talcose and chloritic schists, together with chrome iron ore, and a conglomerate composed of serpentine, peridotite, and chromite, united by a calcareous cement.

From the occasional occurrence of grains of platinum in fragments of serpentine and peridotite, the alteration of which last-named rock is believed sometimes to result in the formation of serpentine, it is generally supposed that that metal originally existed in the form of particles disseminated through rocks belonging to this class. This view relative to the original source of platinum would appear to be corroborated by the fact that, in the district of Miask and in other localities where platinum is found in auriferous sands, those portions of the deposit which rest on serpentinous rocks are always most productive of this metal. It has also been observed that the auriferous sands of the river Mias contain platinum so long as its waters flow over serpentinous rocks, but that, below them, the platinum gradually diminishes in quantity and finally disappears. Platinum is usually accompanied by gold, chrome iron ore, iridium, and iridosmine; and, although generally occurring in small fragments, is sometimes found in the form of nuggets of considerable size; the largest of these yet found weighing about 22 lbs. The average yield of platiniferous sands varies from 4½ to 6 dwt. of platinum per tonne, but, in exceptional cases, it has been known to afford as much as 1½ oz. per tonne. Platinum was first discovered in the Nijne-Taguilsk district in 1825, and from that date to 1877 the production amounted to 148,810 lbs.

The production of platinum in Russia during the ten years ending December 1876, amounted to 590,296 oz. troy, equal to an average annual yield of 59,030 oz. The average quantity of this metal now annually produced in the Ural district is estimated at about 53,000 oz.

No silver or lead mines appear to be at present worked in the Ural, the principal supply of these metals coming from Siberia. A quartz lode at Ekaterinenburg, running south-east and north-west, and traversing a dyke of beresite enclosed in talc schists and clay slates, is known to be argentiferous. This vein contains, near the surface, brown hæmatite, azurite, cerussite, pyromorphite, crocoisite, native silver, and stephanite; while at greater depths iron pyrites, galena, and grey copper ore make their appearance. More or less galena also frequently occurs in the veins of auriferous quartz; but true deposits of lead ore occur in the Alapaewsk district, where cerussite, associated with brown hæmatite, forms nests in a brownish clay. In the Slatoust district galena is found in quartz veins traversing Silurian limestone. No returns of silver or lead from the Ural Mountains are included in the official statistics for 1876.

The occurrence of occasional pebbles of cinnabar among the auriferous sands of the Ural, renders it not improbable that deposits of that mineral may, at some future period, be discovered.

Among numerous other copper deposits, some of which have been but imperfectly examined, is the celebrated cupriferous mass of Miednoroudiansk, in the district of Nijne-Taguilsk, where a metamorphic schist containing the ore is enclosed in limestones belonging to the Upper Silurian formation. The beds course N. 20° E. and dip 7° S.E., but their continuity and regularity are much interfered with by the occurrence of numerous faults.

In the lower horizons these rocks are comparatively little altered, and contain, principally, iron and copper pyrites; while, in the upper, the rock contains oxidized minerals, and is transformed into a clayey ferruginous mass. In this part of the deposit, which is a true gossan, are found cuprite, malachite, azurite, magnetic iron ore, native copper, libethenite, brochanite, &c. This ore sometimes contains 23 per cent. of copper. In 1836 a block of malachite was found in this locality weighing 330 tonnes. From 1814 to 1877 this deposit, which may probably have some relation to the diorites of the Wisokaïa Mountain, produced 2,590,000 tonnes of copper ore. Copper ore deposits are numerous in the Ural Mountains, although very few of them have been worked with the exception of the Miednoroudiansk Mine, which annually produces about 1,200 tonnes of ore. All the other copper mines in the Ural appear to have been abandoned. The bedded deposits of the western slope cannot be considered as having any geological connection with this range of mountains, but as they belong, administratively, to the same group they may be here mentioned.

These deposits occur in the Governments of Perm, Wiatka, Kazan, Ufa, Samara, and Orenburg, and belong to two different formations, the Permian and the Triassic; it is, however, generally impossible to say precisely to which of these two formations each particular deposit belongs. The copper occurs in the form of blue and green carbonate, black oxide, cuprite, copper ochre, volborthite, and, very rarely, as native copper. The sulphuretted minerals, copper sulphides, iron and copper pyrites, and grey copper ore, constitute but a small proportion of the ores present. In 1875 these bedded deposits of copper ore produced 20,000 tonnes of ore, from which 800 tonnes of copper were obtained.

Nickel occurs at Rewdinsk in an almost vertical quartz lode, about six feet in thickness, traversing chloritic slate and serpentine in a direction N. 30° E. The ore is stated to be a hydrated silicate represented by the formula $3R\ SiO_3 + 2H_2O$, in which R represents principally nickel; it contains 18 per cent. of nickel and 12 per cent. of iron, and has received the name of rewdinskite. Cobalt and zinc ores are almost unknown; but several deposits of manganese and chrome ores are worked in the Ural.

Magnetite occurs in a number of large deposits on the eastern side of the Ural chain, but of these only a small number are worked. The magnetite deposits of the Blagodat Mountain and of the Wisokaïa Mountain are well known, and have been described in various Russian and French works.

The Blagodat Mountain [1] consists of augite-porphyry passing into uralite-porphyry; the summit being capped by a compact basaltic rock. The magnetite is distributed in strings and irregular masses, and is very compact, but contains iron pyrites, calc spar, apatite, mica, and analcime.

The magnetite which affords the best iron in Russia is obtained from the Oula-Outasse-Taou Mountain, but only a small quantity is raised. In addition to the above-mentioned deposits of magnetite, many others of less magnitude occur in the Ural. These usually form irregular masses, lodes, or bedded lodes, in hornblendic and pyroxenic rocks, as well as in syenites and in crystalline schists. Red hæmatite is found in many places, but it occurs principally in small masses subordinate to brown hæmatite, and rarely as an independent deposit.

Brown hæmatite is the principal and most abundant iron ore of the Ural, and is extensively worked in various localities. Brown hæmatite deposits occur under very varying conditions, namely:—

1. In small irregular masses in plutonic rocks.
2. As beds in metamorphic rocks.
3. In beds at the contact of the metamorphic rocks with Silurian limestones.
4. In deposits at the contact of metamorphic and plutonic rocks.
5. In accumulations in the lower horizons of the Silurian formation.

[1] H. Müller, *Berg. und Hüttenm. Zeit.*, 1866, p. 54.

6. In beds in clayey sandstone of Carboniferous or Devonian age.

7. As accumulations in the form of nests in Silurian or Carboniferous limestones.

8. As accumulations in alluvium.

Spathic iron ore is by no means plentiful, but sometimes accompanies brown hæmatite, as in the Irkouskane Mountain, which annually yields about 1,650 tonnes of this ore. Sphærosiderite also occurs in the Ural, being worked in Carboniferous sandstone with an annual production of 15,500 tonnes.

The Timan chain, situated in the extreme north, is very thinly inhabited, and comparatively little is known of the mode of occurrence of its minerals.

THE CAUCASUS.—The oldest rocks of this chain are believed to be of Jurassic age, and the most important metalliferous deposits are undoubtedly those of copper ore. Among these the lodes of Alwerd, Sitsimadane, Kawart, and Artan, with the irregular mass of Kiadabek, may be cited as the most important.

The usual gangue is quartz, sometimes associated with gypsum and, more rarely, with heavy spar; in which latter case the lode is seldom rich. The ore generally consists of iron and copper pyrites, with various products of their oxidation. Blende sometimes occurs in more or less considerable quantities, as at Kiadabek, where a nest of argentiferous galena has been discovered. In other cases the ore consists of a mixture, in varying proportions, of argentiferous galena and copper ores, as in the Dambloud deposit.

Deposits of lead ore, properly so-called, exist only in Ossetie to the north of the chain, where they form lodes of which both the gangue and country rock are quartz, protogine, heavy spar, and limestone. The ore consists of galena, blende, iron and copper pyrites, with products of their oxidation.

A deposit of cobalt ore has been found at Dachkessan, Government of Elisabethpol, which takes the form of a vein of diorite impregnated by cobalt ore associated with iron and copper pyrites. The cobalt ore is almost entirely free from nickel; but the workings are now abandoned.

Among the deposits of iron ore that of Dachkessan is one of the most important, and consists of a thick bedded lode of magnetite; while at Tchatach there is a large irregular mass of diorite impregnated with iron glance.

Manganese is found in the valley of the Kwirile River, forming a bed of pyrolusite in Miocene sandstone.

POLAND.—It is probable that mines were worked in Poland during the twelfth century, and from the commencement of the fifteenth century to the end of the sixteenth more lead was produced in Poland than in any other country in Europe. The calamine deposits were discovered at the commencement of the present century, and a more liberal mining law, which was promulgated in 1870, has exercised a considerable influence on the development of the industries of the country.

The deposits of galena in the dolomites of the Muschelkalk are of great historical interest, as they have been worked for many centuries. The most remarkable lead mines are those near Olkusz and Boleslaw. The production of lead from the latter mines was very large during the sixteenth and seventeenth centuries, but fell off considerably towards the end of the eighteenth. At the commencement of the present century calamine deposits were discovered, and the galena is now worked subordinately to the zinc ores. In 1876 only 3,895 tonnes of lead ore were obtained.

Deposits of lead and copper have been long known near Checiny and Kielcé. The lead ores occur in lodes in Devonian quartzites, and have been worked from the fifteenth century. The copper ores, which consist principally of malachite and azurite, have been worked near Kielcé, at Miedziana-Gora, and at Karczovska. The working of these deposits dates from the fifteenth century. During the ten years terminating in 1826, 3,360 tonnes of copper ore were obtained; but the production has since entirely ceased.

The ores of zinc found in Poland are carbonate of zinc, silicate of zinc, zinciferous dolomite stained red by oxide of iron, and zinciferous limestone. The majority of these are found in the dolomite of the Muschelkalk formation. These ores always occur as irregular deposits, or nests, varying in thickness from a few inches to twelve feet, as is also the case in the Scharley Mine in Silesia. The same deposits extend into Poland and are worked at the Barbe Mine. Near Boleslaw the bed is fifty feet in thickness; but the percentage of zinc in the ores is very variable in the different mines. In 1876 six mines produced 59,878 tonnes of zinc ore, and during the same year three zinc works yielded 4,506 tonnes of zinc.

Numerous deposits of iron ore occur in the south of Poland, and iron ore mines are worked near the small town of Daleszycé, where deposits of brown hæmatite containing 40 per cent. of iron are enclosed in rocks of Devonian age. The Carboniferous formation of Poland contains numerous beds of sphærosiderite, of which the thickness is very variable; but this mineral is often found in large masses and is very extensively worked. Brown hæmatite, containing from 25 to 33 per cent. of iron, also occurs in the Muschelkalk and is worked at Bendzin, Czeladz, Sievierz, and Slawkow. The iron ores which occur in the Keuper are, however, much more important, and consist of brown hæmatite and sphærosiderite. The brown hæmatite contains from 35 to 45 per cent. of iron, and the sphærosiderite only from 27 to 35 per cent.; but the latter constitutes the larger portion of the iron ore raised in Poland.

In 1876 iron ore was raised from 79 mines in Poland, the total production of the country being 107,600 tonnes; this yielded 31,168 tonnes of cast iron.

THE ALTAI.—The number of ore deposits which have been discovered in the Altai is very large, amounting in the aggregate to several thousands. The larger number of them occur in the western extension of the chain, in the neighbourhoods of Schlangenberg, Riddersk, Nikolajewsk, and Siranowsk. Several mines are, however, worked near the town of Salair, north of the main chain, while on the other hand the eastern portion is but little known, and no ore deposits are believed to be worked in this region. All the different veins exhibit similar characteristics, being almost without exception lodes traversing sedimentary rocks belonging to the Silurian, Devonian, and Carboniferous periods. Lodes do not often occur in the crystalline slates, and still more rarely in granite. Granites, porphyries, and greenstones constantly occur in the vicinity of the lodes, and several mines are worked in porphyry. The filling of the lodes chiefly consists of heavy spar, quartz, and various sulphuretted ores; the latter are, however, usually much altered near the outcrop, and crystallized minerals are rare.[1]

At the Tschudack Mine, in the Altai, a copper lode from eighteen to twenty-four feet in width is worked in quartz-porphyry; the veinstone is quartz, enclosing copper ores in strings and leaders. In the centre of this lode there is said to be a leader of ore six feet in width containing but little quartz. At a certain depth the ores consist of copper and iron pyrites and copper glance; near the surface various products of oxidation prevail.[2]

[1] B. v. Cotta, "Der Altai," Leipzig, 1871, p. 246.
[2] *Ibid. Berg. und Hüttenm. Zeit.*, 1870, p. 29.

Auriferous sands, frequently containing platinum, are extensively worked in the Altai. In the mining district of Nertschinsk, in eastern Siberia, in the proximity of syenite and granite, crystalline limestones alternate with sandstones, and are traversed by irregular veins which, occasionally, widen out to irregular masses, especially near the contact of dissimilar rocks. These deposits are filled with quartz, calc spar, and brown ironstone, in which galena, fahlerz, molybdenite, iron pyrites, copper pyrites, and blende are enclosed.[1]

The gold production of Siberia in 1881 was 2,614 poods, worth thirty-four millions of roubles.

In Russian Turkestan, deposits are known of gold, silver, lead, copper, iron, manganese, and arsenic; but in spite of their large number a few only are worked. Gold placers are wrought upon a small scale, but the deposits of other metals for the most part remain unworked.

The production of tin in Russia in 1879 amounted to only two tons. Zinc gave an annual average of 4,337 tons, five years previous to 1879, but in that year fell to 4,236 tons. Copper decreased from 3,496 tons, the yearly average of the same quinquennial period, to 3,064 tons in 1879. Lead increased from 1,010 tons, average, to 1,331 tons in 1879. No nickel was extracted in 1879. In the same year 15 tons only of cobalt ores were raised.

The precious metals showed a marked increase during the period 1874 to 1878. In western Siberia the production of gold increased slightly, and in the Ural considerably. At the end of 1879 the number of gold mines belonging to private individuals was in eastern Siberia 1,522, in western Siberia 291, and in the Ural 1,233, making a total of 3,046. The production of gold in the Russian Empire was 32 tons in 1874, 41 tons in 1878, and 42 tons in 1879. The production of silver in 1879 was 11 tons, and of platinum 2 tons 5 cwts.[2]

FINLAND.—The copper and tin ore deposit of Pitkäranta[3] are worked on the north shore of Lake Ladoga, where the rocks consist, principally, of red coarsely granular granite and crystalline slates. Veins of granite frequently occur in which red orthoclase sometimes predominates to such an extent as to be worked for the manufacture of porcelain. Metalliferous deposits are also numerous; the ore occurring as impregnations of copper and iron pyrites, galena, and

[1] Pischke, *Neues Jahrb. f. Min.*; 1876, p. 898.
[2] *Iron*, January 27, 1882, p. 67; from figures supplied by Director Skalkowsky.
[3] G. v. Schoultz-Ascheraden, *Berg. und Hüttenm. Zeit.*, 1876, p. 280.

magnetic pyrites, the gangue being usually quartzose. The only deposit which has been advantageously worked is a bed of sahlite impregnated with copper pyrites and tinstone. Upon this, which occurs in the granite, mining has been carried on for above forty years. This bed, which for a length of nearly one mile and a half has been opened upon by six shafts, has a very constant

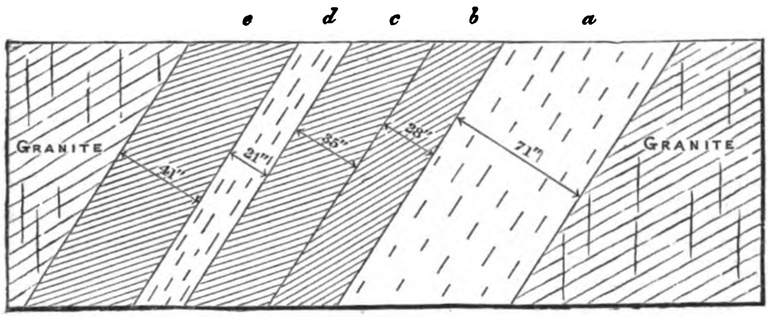

FIG. 74.—Clée Mine, Pitkäranta; section

thickness of about fifteen feet, strikes from east to west, and dips from 40° to 50° S.

The most easterly point worked is opened by the No. 1 Clée Mine, where the entire mass of the deposit is divided by parallel fissures into five beds sharply divided from one another; the ore varies much in richness, and the country rock does not contain any

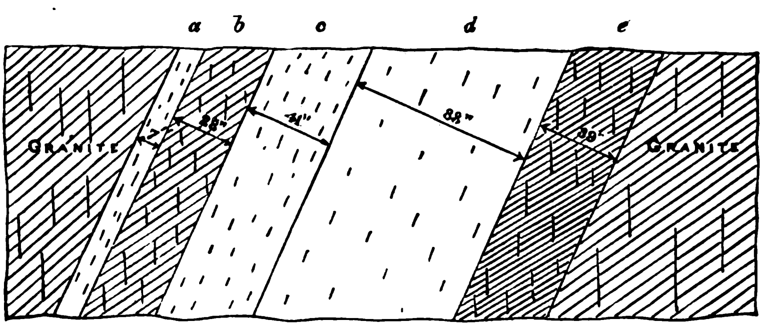

FIG. 75.—Omilianoff Mine, Pitkäranta; section

tinstone. Fig. 74 represents a transverse section across the deposit, in which the band marked *a* is the richest, and contains copper ores only; *b* and *c* contain no ore, *d* contains copper and iron pyrites, while *e* is unproductive.

A little more than half a mile west of this point the rock acquires in the No. 4 Omilianoff Mine a much darker colour, and encloses a bed of dark granular granite three feet in thickness. Here the ore occurs differently, for, whereas in the No. 1 Clée Mine the copper pyrites is finely divided, here it occurs in compact segregations up to the size of the fist, and is often associated with other minerals, such as malacolite, hornblende, quartz, calc spar, garnet, mica, felspar, fluor spar, talc, iron pyrites, magnetite, blende, and tin ore. Iron pyrites occurs in crystals, which sometimes attain a weight of 5 lbs. Neither galena nor magnetic pyrites appears to be present.

Fig. 75 represents a transverse section of Mine No. 3, which is worked for tin ore only. In this section *a* is sahlite with a little copper pyrites, *b* granite without ore, *c* sahlite with tin ore, *d* sahlite with a little tin ore, *e* granite with tin ore; *c* and *e* are the richest in tin, and in *d* tin ore can just be detected, but is entirely absent in the others.

In 1880 Pitkäranta produced 25,513 centners or 1085 tonnes of copper ore, and 482 centners[1] or 20·5 tonnes of tin ore.

The production of Finland in 1880 was as follows:—[2]

Iron ore . .	4,120	centners or	175·2 tonnes
Copper ore .	31,756	„ „	1,350·5 „
Tin ore . . .	482	„ „	20·5 „
Zinc ore . .	5,276	„ „	224·4 „
Lake ores .	880,090	„	37,430·2 „

From 240,663 cubic feet of auriferous sand 17,609 grammes of gold (566 oz.) were obtained.

E. H. Furahjelm, director of the Office of Mines, Finland, in a letter to the editor of *Iron*[3] says that the total amount of the gold washed from auriferous sands in North Finland, in the year 1881, was 20,600 grammes, which, at 3·20 francs per gramme, gives a total value of 65,920 francs, or £2,637

General Summary of the Approximate Production of Metals and Metalliferous Minerals in the Russian Empire during the Year 1880.[4]

	Poods.	Tons.
Iron ore raised	62,493,424	1,003,147·0
Gold produced	2,642	42·4
Platinum	180	2·9
Silver	616	9·9
Lead	69,947	1,112·0
Copper	195,518	3,138·0
Zinc	267,800	4·298·0
Sulphur	5,500	87·0
Chrome iron ore	503,503	8,081·0

[1] 1 centner = 42·53 kilogrammes.
[2] *Berg. und Hüttenm. Zeit.*, 1882, p. 247.
[3] February 10th, 1882, p. 106.
[4] *Engineering*, vol. xxxv. 1883, p. 29.

ASIA AND OCEANIA.

THE INDIAN EMPIRE.

ALTHOUGH the useful metals or their ores are, in British India, scattered over vast areas, they are, with but few exceptions, so sparingly disseminated as to be but seldom capable of being worked with advantage. Gold occurs in the sands of a large number of its streams and rivers, but usually in such minute quantities as to afford a pittance of only a few pence daily to a limited number of indigent washers. In addition to gold thus obtained from the sands and gravels of rivers, abundant evidence exists of that metal having been anciently mined from auriferous veins by means of shafts, galleries, and other excavations. There would appear, however, to be no record of the periods at which these works were executed, and we are consequently without any information as to the conditions under which they were conducted, or with regard to the relative values of gold and labour at the time they were in operation. In the majority of cases, therefore, the existence of ancient workings affords but little evidence of the value, according to modern standards, of metalliferous deposits, since they may have been made by forced labour, and at a time when the metals were relatively much more valuable than they are at present. The lead ores of India, always containing a certain proportion of silver, occur disseminated in beds, pockets, or segregations, but they are seldom found in true veins. Many of these deposits were formerly worked on a very small scale by the natives, but none of those which are at present known would seem to offer sufficient inducement for the introduction of capital, or for the application of improved modern processes.

Ores of copper are of even more frequent occurrence than those of lead, but like those of that metal are seldom found in regular lodes, but occur, on the contrary, in beds and segregations, as well as in the joints of various rocks. These ores were formerly worked by native smelters, who obtained from them copper of good quality but at a cost far exceeding that at which it can now be imported.

Iron ores are abundant, and malleable iron has, from time immemorial, been produced from them in charcoal forges blown with a hand blast. In this way both iron and natural steel are still, to some extent, manufactured by the hill men at various points in the interior; but the metal so produced can no longer, either in price or quality, compete with that manufactured upon a larger scale in Europe, and subsequently imported into the country. Numerous attempts have been made to introduce modern processes of iron and steel making into British India, but the results have, without exception, been unsatisfactory. This repeated want of success is probably in part attributable to various circumstances of a kind often unfavourably affecting enterprises of this description, but is perhaps mainly due to the circumstance that the largest and richest deposits of iron ore are situated at considerable distances from a sufficient supply of suitable fuel.

GOLD.—The original derivation of the principal portion of the gold of Peninsular India is doubtless from the quartz veins traversing various metamorphic and sub-metamorphic rocks. There is also reason to believe that in some parts of the country gold occurs, independently of quartz veins, in certain chloritic schists and quartzites as well as, possibly, in one or more varieties of gneiss.

According to Professor Ball, late of the Geological Survey of India:—"The presence of gold either as an original deposit, or as a detrital product from the older rocks, has not as yet been proved in any member of the great Vindhyan formation. But in the next succeeding formation several of the groups included in the Gondwana system are believed to contain detrital gold; of these the evidence seems clearest in the case of the Talchir. It is almost certain, however, that the gold obtained in the Godavari and in its tributary near Godalore or Mungapet, is derived from rocks of Kamthi age, and the gold of the Ouli River in Talchir in Orissa is derived from sandstones, but whether from those of the Barakar or Kamthi groups is not certainly known, as both occur in the same river section. It is of course natural that the sedimentary rocks which first filled the previously existing hollows and basins should contain gold as well as the other materials derived from the degradation of the older metamorphic rocks, but gold is also probably present, though its existence has not yet been proved, in some of the still younger groups.

"In so far as Peninsular India is concerned, the only other sources of gold are the recent and sub-recent alluvial deposits which rest on the metamorphic and sub-metamorphic rocks. Passing to the extra-peninsular regions we meet with evidences of the existence of gold in rocks of several different periods. In Ladak certain quartz reefs which traverse rocks of the Carboniferous period are almost certain to be gold-bearing, as particular streams which rise within their limits contain auriferous sands. In Kandahar gold occurs, as also do some ores of other metals in rocks of Cretaceous age. Here the deposit is an original one, and is connected with the intrusion of trap.

"Lastly, all along the foot of the Himalayas from west to east, from Afghanistan to the frontiers of Assam and Burma, the tertiary rocks which flank the bases of the hills, and which occur also in the Salt range and in Assam, south of the Brahmaputra, are more or less auriferous. But this gold is all detrital, and was no doubt, in the first instance, derived from the crystalline metamorphic rocks of the higher ranges which are otherwise known to contain gold."[1]

The gold-fields of Madras have recently attracted so much attention and have absorbed so large an amount of British capital, that a description of the auriferous deposits of that portion of British India may be desirable.

The excitement caused by recent reports relative to the riches of the Wynaad has also directed attention to various adjoining areas in southern India where crystalline rocks prevail. Among these the Travancore State has been to some extent prospected, but it does not appear in any of the early accounts as a gold-producing region, and the trade of gold washing seems to be unknown there. Mr. King, who recently reported on this subject to the Travancore Government, states that the so-called quartz reefs are not really veins, but merely the outcrops of beds of quartzite, associated with felspar, which run with the foliations of the gneiss. Although minute traces of gold may sometimes be detected in these rocks by assay, the amount present is far too small to render them of any commercial value as a source of that metal.

The Wynaad forms a terrace of mountain land lying between the low country of Malabar and the lofty plateau of the Nilgiri Mountains, and is separated into three portions, known respectively as North, South, and South-East Wynaad. The south-eastern division of the Wynaad, in which are situated the principal veins of auriferous quartz, is now included in the Nilgiri district; but with reference to the earlier notices of the occurrence of gold, it will be more convenient to follow Mr. Ball, and to treat it as belonging to the Malabar district, in which it was formerly

[1] V. Ball, "A Manual of the Geology of India," Part III. "Economic Geology," p. 176, Calcutta, 1881. This carefully prepared volume, to which I am indebted for a large amount of information, should be consulted by every one specially interested in the mineral resources of British India.

included. In a report of a joint commission from Bengal and Bombay upon the condition of the Malabar province in the years 1792-93, allusion is made to the fact that the Rajah of Nilambar claimed a royalty on all gold found in his territory, and in the latter year some steps were taken by the then Governor of Bombay to ascertain the value and extent of the gold mines of this region. The next mention of the occurrence of gold in the district is made by Dr. Buchanan[1] in 1807; he alludes to the gold mines of Malabar and states that a Nair who had the exclusive right of mining paid a small annual tribute for the privilege. In the year 1827 Mr. S. Young stated that fine specimens of gold had been found to the west of the Nilgiri Mountains in the beds of various streams, and in 1830, Mr. F. H. Barber,[2] who was examined before the Lords Committee on East Indian affairs, asserted that gold was obtained not only in Coimbatore but throughout the tract of country lying west and south of the Nilgiri and Kunda Mountains. He had often witnessed the process of gold washing, and estimated the area over which the soil was impregnated with gold at 2,000 square miles. In the year 1831 Lieutenant Nicolson was appointed to prospect for gold-fields, and also to purchase on behalf of Government. His report as to the extent of the mines and the possibility of their being worked advantageously by British capital, was on the whole sanguine, and he suggested that stamping mills for the treatment of gold quartz should be erected at Coopal. After the receipt of the report of a committee, in 1833, condemning mining in the low country of Malabar as a European industry, the Governor in Council came to the conclusion that it would be inexpedient to work these veins. In 1857 and 1858 attention was again directed to these gold mines by the Collector of Malabar, who described them as extending for a distance of from thirty to forty miles along the western face of the ghâts, and in some places even reaching to their summits. At this time the taxes payable by the rajahs for the right to mine had fallen into arrears, and many of the older miners and their descendants would appear to have migrated to the coffee plantations of the Western Wynaad. Among those who in 1865 were attracted to the Wynaad were two Australian miners, Mr. H. L. Sterne and Mr. G. E. Withers, while shortly afterwards the erection of quartz crushing machinery on the Skull Reef was due to the enterprise of

[1] "A Journey from Madras through the countries of Mysore, Canara and Malabar," London, 1807, vol. i. p. 441.

[2] *Journal Med. and Phys. Soc. of Calcutta*, vol. iv. p. 48; evidence ordered to be printed, April 2nd, 1830.

Mr. J. W. Minchin. The results yielded by this and other appliances erected elsewhere for the same purpose, were not satisfactory, and in 1875 Mr. W. King, Deputy Superintendent of the Geological Survey of India, visited the district, and his report with a map of the Wynaad was subsequently published.

The gold-bearing area consists of granite, gneiss, and various metamorphic rocks, traversed by veins of quartz, which with their branches are auriferous. He describes the gold as occurring originally in large reefs or veins of quartz, as well as in spurs branching from them, and sometimes in the country rock itself. In certain leaders, as well as in the casings of the veins, gold is sometimes visible either in quartz, in crystals of iron pyrites, or in pseudomorphs composed of limonite resulting from the alteration of that mineral. The gold of the reef is usually very fine, and occasionally occurs associated with pyrolusite. The prevailing direction of the quartz reefs is from south-south-east to north-north-west, but owing to the irregularity and occasional flatness of their underlie, there is sometimes considerable difficulty in tracing them. Their outcrops are without exception white, and generally speaking it is impossible to say by mere inspection whether they are auriferous or otherwise. The Monarch Reef is said to be traceable for a distance of about nine miles.

The report of Mr. R. Brough Smyth on the Wynaad gold fields contains the results of his explorations during the years 1879 and 1880. In the district to which his attention was principally directed, and which covers an area of 500 square miles, he records having counted nearly 200 outcrops of quartz rock. These do not, however, necessarily represent so many distinct veins or reefs, and it is not improbable that a certain proportion of them may be mere veinstone boulders, which, having become detached, have rolled down the sides of declivities until arrested by some accidental obstruction.

The reefs are represented as being generally wider and proportionately richer than those in almost any part of Australia, but there are no deep accumulations of auriferous drift such as characterise the gold regions of that country and of California. Numerous ancient workings indicating very different degrees of mining skill are met with; these comprise open cuttings on the outcrops, vertical and inclined shafts on the reefs, with occasionally levels, and shafts and galleries combined. Some of the vertical shafts, which are perfectly perpendicular, have been sunk in solid quartz to a depth of seventy feet. The rock obtained from these various workings appears to have been ground by hand mullers, washed in a wooden dish, and, perhaps, subsequently amalgamated. The country is so covered by these ancient tailings that Mr. Brough Smyth compares its condition to that of an abandoned Australian washing. The quartz from the veins in this region occasionally contains cavities enclosing minute crystals of native sulphur.

Many of the samples of gold quartz forwarded from the Wynaad to London for assay yielded satisfactory results, but it must not be forgotten that, in such cases, the amount of gold found will be influenced rather by the selection of the specimens than by the care taken by the assayer. For the present it is not the intention of Government to levy any royalty or other tax upon this industry, as it is thought desirable to attract labour and capital to the gold-fields. Notwithstanding this advantage, however, it is not improbable that the experience of the pioneers in this industry may be acquired at a considerable cost. In his special report to the Government Mr. Brough Smyth has fully discussed the circumstances which he considers led to the failure of the Alpha Company, the first to establish itself in the Wynaad. He regards both the machinery and management as having been unsuitable to the requirements of an economical system of working. As, however, a large amount of plant and machinery has now been sent out, and the management is, in some cases at least, in the hands of experienced gold miners, it may be hoped that, in some cases, the conditions necessary for substantial success may be ultimately brought together.

The Wynaad[1] gold region consists of a more or less undulating table-land averaging about 3,000 feet above sea level, and lying at the eastern foot of the Nilgiri Mountains, which, being the highest mountain range of Southern India, rise to a height of some 8,000 feet above the sea. The climate during the greater portion of the year is temperate and equable, but, during the monsoon, the rainfall averages somewhere between 150 and 200 inches. The monsoon of 1882, however, exceeded 400 inches, being the heaviest on record.

The country rock mainly consists of a hornblendic gneiss containing a large preponderance of quartz, and is, as a rule, except in close proximity to the surface, where it is liable to decomposition, extremely hard. No well authenticated instance of a vein settling

[1] I am indebted to Mr. George Seymour, A.R.S.M., for much valuable information relative to the Wynaad gold-fields.

down into and "living" in the country rock, has been observed. Owing to this fact, and to the circumstance that most of the quartz has, up to the present time, been sought by shallow adits, but little mining has been carried on which could enable any reliable opinion to be formed respecting the character and continuity of the reefs in depth. No shafts of any importance have been sunk, and some adits which were started to explore the country under favourable topographical conditions had to be abandoned owing to the hardness of the rock, which proved too much for the labour available. The course of the reefs varies from N. 20° to 40° W., the dip being generally easterly, at an angle of from 30° to 35° with the horizon. Some of the veins appear to incline at a greater angle, but these are exceptions to the general rule.

Whatever may prove to be the future of the Wynaad as a gold-producing country, no doubt can exist as to the extent of the mining operations which were carried on at periods which cannot be approximately fixed even by the uncertain evidences of tradition. The deepest shafts re-opened had been sunk to a depth of about twelve fathoms, and in every case had struck a reef more or less auriferous. It is hardly fair to assume that the presence of water caused the abandonment of the works, although it might certainly entail their temporary suspension during the prevalence of the monsoon. The shafts referred to were, in two instances at least, namely, on the boundaries of the Perseverance and the Devalah Central Companies, and on the course of the Ellumbullay Reef, sunk to a considerable depth on the normal course of the reefs. In each case the numbers of shafts sunk within a given area, and the character of the surrounding country, would lead to the conclusion that the miners had found sufficient inducement to justify them in persevering in their labours. It is of course open to question whether the same yield of gold would afford a profit under the present conditions of paid workmanship as under the old *régime* of compulsory labour. In one instance as many as fifteen or twenty shafts had been sunk within an area of as many yards square, but the miners, whoever they may have been, seem to have had no idea of inter-communication by means of levels.

The occurrence of auriferous reefs in the Wynaad is beyond doubt, but Mr. Seymour is of opinion that their continuity in depth and strike is a very important question, and that until their stability in these respects has been established the prospects of gold mining in the district must remain uncertain.

Perhaps the most noteworthy feature in connection with these deposits is their want of continuity in strike and dip, under circumstances which would lead a casual observer to the conclusion that they were persistent in both. As an instance of this, a presumably stable and continuous outcrop of quartz, on investigation by means of a transverse trench, shown in Fig. 76, proved to be no more than a row of symmetrically disposed superficial boulders, sufficiently angular, notwithstanding, to justify a hasty supposition that they represented the outcrop of a reef. In this case the main axis of the boulders was that of the normal strike of the district, 20° W. of N., yet not a single stone could be found six feet below the surface. In another locality a reef showing a

FIG 76.—Quartz boulders, Wynaad.

pronounced strike and a width of many yards on one side of a gully, failed to show any trace on the other.

A reef was found parallel to the slope of a hill side, and another lying parallel to it was found by means of an adit. Outcrops having been seen on the slope above underlying in the same direction, it appeared probable that other parallel veins would be found; yet after driving a cross-cut for a considerable distance through the hill none were discovered. In another instance a strong outcrop some nine feet in thickness was discovered on the brow of a hill, but all explorations to prove it in depth were unsuccessful, notwithstanding an exceptionally favourable contour of the ground, and no reasonable doubt can exist that it pinched out within a short distance from the surface.

This tendency of reefs to dip with the hill sides is common in the Wynaad, but it is, however, possible that the contour of the hill itself may sometimes be due to the projecting influence of a reef, which, acting as a capping or shield, protects it from the destructive effects of the monsoon for an indefinite period. The landslips which occur during and subsequent to the monsoon have, in many cases, had the effect of dislocating the reefs, and in some instances of causing one reef or ledge to be regarded as two distinct and independent veins.

A careful consideration of the foregoing facts lead to the conclusion that the auriferous ledges of the Wynaad cannot generally be accepted as true veins. The character of the various reefs is essentially identical throughout the district; consisting as they do of massive white quartz, in which occur irregular aggregations of pyrites, which is frequently arsenical. Limonite, hæmatite, chalcopyrite, and occasionally native sulphur are also present. In almost every instance the gold occurs in association with these minerals, and Mr. Seymour does not hesitate to express his belief that some of the specimens shown in London, purporting to have been brought from the Wynaad, were not indigenous to that district. It will, he believes, be eventually proved that paying gold exists only in conjunction with pyrites, and more especially with arsenical pyrites. The reefs vary in width from a few inches to twenty feet. Assays of the Wynaad ores have afforded results varying from 2 dwt. up to 20 oz. of gold per ton; the highest results being in every instance obtained from arsenical pyrites.

Mr. J. Darlington, who visited these gold-fields in 1883, and who has consequently had the advantage of examining the workings of the various mines when in a more advanced stage, is of opinion that true veins of auriferous quartz sometimes occur in the Wynaad. Irregular patches, lenticular interfoliations, and bedded veins are, however, more frequent; and in not a few instances what had been taken for the outcrop of a vein has proved to be nothing more than a quartz boulder fallen from a reef situated at a higher level.

The bedded reefs usually dip with the surface of the hill in which they are enclosed, and are often covered by a clay-like material resulting from the decomposition of the superincumbent gneiss; while the rock below has been to some extent protected from alteration by its capping of quartz. In other cases, the quartz has become fissured, and the rock beneath has been reduced to the state of clay, in which portions of the reef, which have become detached, have been embedded, as shown in Fig. 77, which represents a section of Rhodes Reef after a drawing by Mr. Darlington. At right angles to this section the reef forms a saddle or anticlinal.

Some of the shafts sunk by the ancient miners would appear to have been made in pursuit of the beds of auriferous gravel. Generally speaking, the quartz of the Wynaad is to some extent auriferous, but the trials hitherto made on a practical scale have, without exception, proved unsatisfactory. It is therefore to be feared that in too many instances the mines of this district must fail to be remunerative; and it is much to be regretted that more haste than sound judgment is so frequently exhibited by those who "invest" in companies belonging to this class.

In the year 1802 Captain Warren, who was at that time engaged in a survey of the eastern frontier of Mysore, instituted

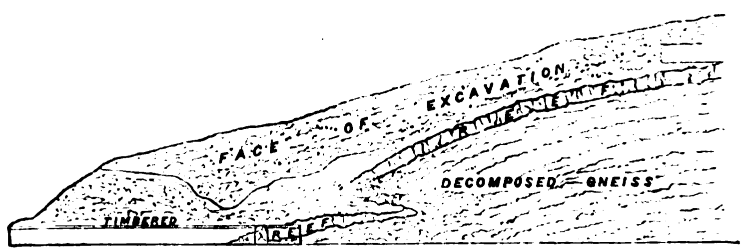

FIG. 77.—Rhodes Reef; transverse section.

inquiries which led to the discovery that gold-washings were in operation near the village of Wurigam, the modern Urigam, or Ooregaum, and that actual mining was being carried on near Marcurpam, where the quartz extracted was first pounded into dust by women and afterwards washed. The recent history of the gold industry of Mysore may be, to some extent, gathered from the following statements, contained in the reports of successive administrations. In 1868 it was stated that alluvial gold was occasionally found near Betmangla, but in quantities insufficient to repay the expense of collection. In 1870 it was said that at some points along the foot of the Hemagiri Hill, about sixpence per diem could be made by washing certain sands for alluvial gold. In 1872—1873 four pounds weight of gold was collected in the Betmangla taluk, and in 1873—1874 six pounds weight of that metal was obtained in Kolar. In 1874—1875 three pounds weight of gold was obtained in Kolar, besides twenty rupees' worth in the Honuali taluk of the Shimoga district; and permission was granted to a Mr. Lavelle, for three years, to prospect for gold and other metals. Leases for twenty years were, if required, to be subsequently granted for blocks of land of not more than two square miles, and not exceeding ten in number. In 1875—1876 we are told that the terms of the leases had been modified, and that prospecting was progressing, but in 1876—1877 we learn that the Urigam or Ooregaum Company had not commenced operations. In the reports for 1877—1878 and 1878—1879 there is no information relative to this subject; while in the tables relating to mines and quarries the statistics of gold and ironstone are lumped together. In the last report, however, 1879—1880, it is stated that potstone and iron ores are the only minerals now worked in the province.

The Kolar gold-field is situated in the province of Mysore, about forty miles east of Bangalore, on a vast plain covered with grass and scrub.[1] The principal formation of the district is a granitic gneiss passing into a syenitic or hornblendic variety of the same rock. A band of greenstone trap, about two miles in width, traverses the district in a north and south direction, and it is in this rock that the auriferous reefs occur.

Between this trappean formation and the gneiss to the east of it, broad bands of rock, including hornblende and mica schists occur; while it is bounded on the west by a continuous ridge of a banded ferruginous quartzose rock, rising in places to a height of over 200 feet, and towards the southern extremity of the field showing evidences of contortion. This rock has in some places a jaspery appearance, in others is composed of thin alternate laminæ of quartz and siliceous hæmatite, while in one or two localities a band of iron ore opens out to a width of several feet, and appears to have been at one time extensively worked. Several bands of schists, including hornblendic schist, mica schist and chloritic schist, occur between this ridge and the gneiss, and, like the shales on the eastern side, dip towards the trappean rocks.

The band of trap in which the auriferous reefs occur, varies in structure from coarsely crystalline diorite to fine-grained greenstone, the former appearing to pass by slow gradations into the latter. Where the crystalline structure is most fully developed, boulders of a more or less spherical form often lie scattered over the surface, or form ridges, several of which occur at various distances apart, coursing in a north and south direction. These surface boulders

[1] Information kindly supplied by Mr. J. H. Johns of the Nine Reefs Mine.

appear to decompose slowly, but portions of the same rock brought up from a depth of thirty or forty feet below the surface, disintegrate rapidly upon exposure, and scale off in numerous concentric coats.

The general bearing of the quartz reefs is from 4° to 10° W. of N. and they invariably occur in the fine-grained eruptive rock. Deposits of unproductive quartz, usually of very limited extent both in length and in depth, are often met with in the more coarsely crystalline variety. In the reefs occurring towards the eastern and western limits of this formation little or no pyrites has been found, but those near the centre of the mass contain a considerable proportion of mispickel; and occasionally a little iron pyrites, pyrrhotine, and chalcopyrite are also met with. The walls of the reefs are often faced more or less thickly with chloritic schist, which occasionally encloses garnets. The greenstone is usually decomposed to a greater depth within a few feet of the reefs than at a more considerable distance from them, and the resulting clay, of a greenish-yellow colour, is the so-called "mullock" of Australian miners, which, when it occurs in the form of a horse, or as strings in connection with the reefs, often contains a little gold.

Some of these reefs have been worked to considerable depths over great lengths, but no records of these former workings appear to exist. They have been generally worked by open-cast, but it has not been determined by what method the reefs were attacked and the water removed from the workings. Mr. Johns carefully examined a portion of a reef standing in one of the old workings in the Nine Reefs Company's property, with a view to discovering the method adopted by the former miners for breaking the rock; but although it is very hard and showed no signs of decomposition, he could neither find traces of bore-holes nor anything to indicate that borers had been employed. He, however, from time to time found pieces of charcoal in the *débris* with which the old workings were filled, and this, in the absence of any traces of bore-holes, would rather point to the ancient method of fire-setting as that by which the reef had been worked.

Gold occurs in Hyderabad, or the Nizam's Dominions, and mention of it is found in various works published about the beginning of the present century. Within the province of Orissa gold-washing has been carried on in the Native States of Dhenkanal, Keonjhar, Pal Lahara, and Talchir; but as is the case in many other parts of India, it is on the whole an unremunerative business. In Bengal small quantities of gold are disseminated in the sands of the streams in the Midnapur and Bankura districts, as well as in those of the Chutia Nagpur province, which includes the greater portion of the hilly region on the south-west frontier of Bengal. The localities in the Manbhum district in which gold-bearing sands are known to exist, are very numerous, and in its more northern portion there are probably but few streams of which the sands are not to some extent auriferous. By a systematic application of the operations of two gold-washers for a period extending over three months, Professor Ball[1] was enabled to define the area in which gold is comparatively most abundant. The results thus obtained were found not only to agree with the traditional information of the gold-washers, but they also very conclusively showed that the area over which the largest amount of gold is disseminated corresponds with a tract comprehending a particular series of stratified rocks. These, which consist chiefly of mica schists and quartzites, are all included in the sub-metamorphic series. Although, however, more gold was collected from superficial deposits within this area than elsewhere, those portions of the district in which metamorphic rocks are alone present did not prove entirely barren. The boundary between these two formations coincides with a line drawn from Simlapal on the east, through Bara Bazaar, to a point a little north of Ichagarh on the west, and thence continued into the Chutia Nagpur highlands. South of this line sub-metamorphic rocks almost entirely prevail, while beyond the Manbhum frontier they extend into Singhbhum and Lohardaga. During the period of three months before referred to a diary was kept in which a record was entered of the amount of gold obtained daily, as well as of the character of the rocks where the different washings were made.

An analysis of these several records shows that in the sub-metamorphic rocks the average amount of gold daily collected was ·4 grain, while in the metamorphic rocks it was only ·16 grain. With respect to this very small yield of gold Mr. Ball remarks that the washers were often working on strange ground, and that moreover they had frequently to walk a distance of some miles to the point at which their operations were to commence. To the above must also be added the fact that their day's pay being assured to them they contented themselves with a very limited amount of physical exertion. In Singhbhum gold occurs under nearly the same conditions as in Manbhum, except that in the former district it would appear to be entirely confined to the sub-metamorphic rocks. In Singhbhum quartz veins are

[1] "Manual of the Geology of India," Part iii. 1881, p. 190.

abundant in certain shales and slates to the north and west of Chaibassa, and it is not improbable that some of these may be auriferous. In the State of Jashpur the gold-washers find it more profitable to work the ancient alluviums of the valleys than to wash the more recent sands and gravels of the streams. At some distance from its banks, and on both sides of the river Ebe, there are tracts which have been completely honeycombed with shafts of from 10 to 30 feet in depth by successive generations of gold-seekers. In the Udepur State the gold-seekers work in pits similar to those on the banks of the river Ebe in Jashpur, and the average amount of gold daily collected by each washer is stated to be about three grains.

Out of the four divisions under which the Central Provinces are classified the Narbada division is the only one which returns no gold-washers. The other divisions contribute as follows: Nagpur 139, Jabalpur 52, and Chatisgarh 12.

It is stated that in Rajputana gold dust was formerly obtained from the sands of the Luni and Khari rivers, but gold-washing appears to be no longer carried on in that country.

In the Presidency of Bombay the districts of Dharwar, Belgaum, and Kaladgi, in the Southern Mahratta country, with the province of Kattywar, include all the known gold-bearing rocks. Mr. R. B. Foote,[1] of the Geological Survey, regards the metamorphic rocks of the gold-bearing areas of the Dharwar district as belonging to three distinct groups, each characterised by specific lithological peculiarities. These he distinguishes as the Dhoni, Kappatgode, and Surtur groups.

The Dohni group is composed of hæmatitic, hornblendic, chloritic, and micaceous schists, with which are associated several beds of white and greyish limestone. Above this comes the Kappatgode group, consisting of hæmatitic and argillaceous schists, which are frequently mottled, but of which the prevailing colours are white or reddish buff. The third, or Surtur group, is made up of hornblendic and chloritic schists associated with massive dolerite. Quartz veins occur throughout these groups, but according to the native washers auriferous sands are found only in streams rising in the Surtur series.

In the Surtur group the outcrops of the quartz reefs, which usually run parallel with the bedding, have generally been more or less broken up by gold seekers; in the other groups the quartz

[1] *Records Geol. Surv. Ind.*, vol. viii. 1874, p. 133; *Mem. Geol. Surv. Ind.*, vol. xii. 1876, p. 259.

veins often course across the strata. The Hati Kati Reef is in the Kappatgode series, and in its *débris* Mr. Foote found traces of visible gold. This reef contains iron pyrites, besides other sulphides, and it has, to some extent, been opened at the outcrop by rude sinkings and shallow trenches indicative of native mining.

It has been stated that all the rivers of the Punjab, the Ravi alone excepted, contain auriferous sands, and although this may not be literally correct, it is still an undoubted fact that the rivers and streams of this province do, as a general rule, contain gold. This is equally true with regard to those rising in distant ranges of crystalline rocks, as well as of those having their sources in lower detrital hills of Tertiary age. The practice of gold-washing is in the Punjab doubtless of considerable antiquity, and under the Sikh Government the taxes upon this industry amounted to one-fourth of the gross produce. Now, however, as in most other parts of India, the income from this source has either dwindled to very small proportions or has become entirely extinct. The districts of the Punjab in which gold occurs are Bannu, Peshawur, Hazara, Rawalpindi, Jhilam, Amballa, and certain Native States.

Assam has long been famous for its production of gold, and it has been stated by various authors that all its rivers contain gold-bearing sand; some, however, limit this general statement to those which rise in the northern hills. It would, however, appear that there are few streams in the districts of Darrang, Sibsagar, and Lakhimpur which do not yield gold. A large proportion of the gold obtained in Assam is apparently derived from the degradation of rocks of Tertiary age; that, however, which is found in the upper reaches of the Brahmaputra probably comes directly from the crystalline rocks.

Within the limits of British Burma gold has been found in the beds of the Irawadi and some of its tributaries, in the Pegu division, and in the beds of the Sittang and its tributaries. The Tavoy river and the Great Tenasserim and its tributaries in the Tenasserim division, also contain auriferous sands, but gold-washing would appear to be by no means a remunerative business. In the Upper Irawadi at Bhamo and near Thingadhaw, gold is obtained from auriferous sands. Some miles nearly due south of the last locality is a small rivulet the sands of which are auriferous, and where, it is stated, each washer could earn the equivalent of three shillings a day. A few miles nearer Thingadhaw the Ponnah creek contains gold, but the washers are described as being miserably poor.

SILVER.—Although the natives of some parts of India were able long ago to separate gold from silver, and to extract the latter metal from argentiferous galena, there appears to be no direct evidence that silver was ever largely produced in the country. The extraction of silver from argentiferous galena is probably still practised in Kandahar and Kashmir, but the only region in which this industry is regularly carried on is in the Shan States which are tributary to Siam. Specimens of silver ore and even of native silver are stated to have been found in many parts of India, but the quantity has always been exceedingly small, and in many cases furthur evidence of its occurrence in the localities indicated would be desirable. It follows that any silver which may have been hitherto found in India otherwise than in association with galena, is of greater mineralogical interest than commercial importance.

LEAD.—At the present time lead is produced in British India in very small quantities only, although there is probably no metal, with the exception of iron, of which the ores were formerly so extensively worked. Evidence of this is afforded by the extent of the ancient lead mines of Southern India, Rajputana, Balochistan, and Afghanistan.

In the Presidency of Madras lead ores have been found; in Kadapah, at Jungumrazpilly and Cotelur; in Karnul, at Gazalpully and Koilkontla; in Bellary, in the Sandur Hills; and in Palnad at Karampudi. Mr. King describes the Jungumrazpilly mines as follows: "The old and now deserted lead workings are at the south end and east side of the low ridge, just north-north-east of the village. The pits or galleries have been excavated between beds of dark grey siliceous limestone which is impregnated with strings of white and dull blue quartz. These rocks are referred to the Cumbum division of the Nallamallay group of the Karnul series. Granular sulphide of lead is disseminated in very small quantities through the blue quartz. In the white quartz there are faint traces of copper. The strings of quartz have been deposited in north-north-east and south-south-west fissures, having a dip of 60° westward, the strata lying at 50° E. by N. The old workings are to a great extent filled up with the excavated fragments of rock and are now overgrown with jungle."[1] Lead ores from this locality contain from 10½ to 13½ oz. of silver per ton. The origin of these extensive excavations is lost in obscurity, although it is known that the mines were wrought by the Hindu kings of Bijanagar, and subsequently by the Mohammedan

[1] *Mem. Geol. Surv. Ind.*, vol. viii. 1872, p. 273.

nawabs of Kadapah in the time of Halim Khan. They were afterwards worked by Hyder and Tipu; the latter of whom is said to have destroyed all documents relating to them.

In Bengal, within the limits of the Bhagalpur division, lead ores have been found in the Sontal Parganas district at or near the following localities: Sankera Hills, Tiur Hill, Bairuki, and at Panch-Pahar or Akasee.

In the Province of Chutia Nagpur lead ores have been found in Manbhum at Dhadka; in Hazaribagh at Mahabagh, Baragunda, Mehandadi, Barhamasia, Nawada, Khesmi, Mukundganj, Parseya, and Hisatu; in Lohardaga at Barikhap and Sili; in Sirguja at Bhelounda, and Chiraikund. In all these places the rocks in which the veins occur belong to the metamorphic series. At Dhadka in the Manbhum district in a hill of mica schist close to a village called Jani Jor, near an outlying house belonging to the village of Dekia, a deposit of galena was discovered in 1869 by some Kumars when searching for iron ore. The galena from this locality contains from 60 to 80 oz. of silver per ton of ore, and occurs in lenticular masses associated with hæmatite and quartz in a true lode. Lead ore from Hisatu is first mentioned in a letter addressed to Warren Hastings and the Council, dated Calcutta, 1777. At the present time the old excavations and *débris* so obscure the outcrop at this place, that without making fresh openings it would be impossible to form any opinion as to the precise nature of the deposit. The neighbouring rocks are gneiss with hornblendic and micaceous schists.

In the Central Provinces lead ores have been found in Sambalpur at Talpuchia, Jhunan, and Padampur; in Raipur at Chicholi; in Nagpur at Nimbha; in Jabalpur at Sleemanabad; and in Hoshangabad at Joga. With but two exceptions these deposits occur in metamorphic rocks; the exceptions being Padampur, where the country rock is a limestone belonging to the Vindhyan series, and Joga, where galena occurs in limestone of lower transition age. The existence of galena on the banks of the Mahanadi, near Jhunan in the Sambalpur district, was known by local tradition, but the exact spot where it occurs was not discovered until 1874, when by cutting trenches at right angles to the granitic rocks a lode containing that mineral was discovered. The lode, where opened upon, was from 16 to 19 inches in width, the veinstone was principally composed of quartz, and the galena obtained from it yielded lead containing 12 oz. 5 dwt. of silver per ton. In the year 1875 a cutting was made with a view of tracing this lode inland from the banks of the river, but there being no one on the spot capable of carrying on the operations, the alluvial covering was not sufficiently removed to determine whether the lode was continuous or otherwise. In the year 1868 a discovery of galena was made by some stone-breakers who were employed in preparing road metal, about three miles west of Chicholi in the Raipur district. Specimens of galena subsequently examined contained about 10 oz. of silver per ton of lead. The locality was visited by Mr. W. T. Blanford [1] in 1870, who describes the ore as occurring in a true vein, largely composed of quartz, traversing granite or granitoid gneiss and hornblende schist passing into diorite. In addition to quartz the vein contains pink felspar, green and purple fluor spar, epidote, and traces of the carbonates of copper. The galena is thinly disseminated through the veinstone, but Mr. Blanford, on the whole, did not consider the indications unfavourable.

Galena occurs in Ajmir, Alwar, and Udepur in Rajputana, and has been mined for somewhat extensively at the foot of the Taragarh Hill, close to the city of Ajmir; the other localities being of less importance. The mines, of which considerable traces still exist, were at one time farmed by the Mahrattas, and it is stated that their suspension was due to the Mutiny and the desire of the Government to prevent the extraction of lead which might be used for the manufacture of bullets. According to Mr. Hacket [2] the ore occurs in a number of approximately parallel veins, traversing a quartzite of sub-metamorphic or upper transition age in nearly the same direction as the strike of the rocks. The galleries followed the courses of these veins, and were only sufficiently large to allow of the miners crawling through them. The ores were brought to the surface in baskets, which were passed from hand to hand by a number of coolies seated within reaching distance from one another. A considerable discrepancy exists in accounts relative to the amount of lead produced at these mines. In 1830, Captain Dixon placed it at only 42 tons 10 cwts. per annum; on the other hand it is stated in the local gazetteer, as well as in the Settlement report, that about the year 1818 their annual production was from 340 to 400 tons of metallic lead. None of the accounts of these mines mention silver as occurring in the ores. In 1846 the Ajmir magazine ceased to receive the metal produced, and the mines were consequently abandoned.

[1] *Records Geol. Surv. Ind.*, vol. iii. 1870, p. 44.
[2] *Ibid.*, vol. xiii. 1880, p. 247.

In Bombay galena occurs in Jubhan, and at Khandelav Lake in the Panch Mahals district in Gujarat. The galena contains about five ounces of silver to the ton of ore. No attempt to work these mines has been made since 1874.

In Balochistan there are ancient lead mines at Sekran, but they are now deserted. These mines are described as having been very extensive, and it is stated that they formerly employed 200 men. The vast quantities of slag found in the district testify to the once great extent of the industry.

In the Punjab Himalayas there are a number of localities, especially in the Kulu and Simla districts and in the Sirmur State, where lead ores occur, which, in some cases, have been worked on a very limited scale. In the Simla district galena occurs on the east bank of a stream near the village of Chapla, where the vein runs parallel to the bedding of the rocks, which are slates intercalated with thin beds of limestone. Mining and smelting were for some time carried on in this locality under European management, but as all operations have now ceased it may be concluded that the undertaking was not a profitable one. On the banks of the Tons river, about twenty-five miles above Kalsi, is a tract of country surrounding Swinj, partly included in Sirmur and partly in Jaunsar, where lead mining has been somewhat extensively carried on. Mr. H. B. Medlicott, who visited this locality in 1862, says that only one mine was then open. He describes the lode as being about two feet in width, well defined, and with a dip at an angle of 70° towards east-north-east. The galena exists chiefly in the form of a regular leader near the foot wall; there is, however, another distinct band, consisting chiefly of quartz, containing blende, galena, and iron pyrites. The rocks in which this vein is enclosed consist of slates and limestones of the Krol and Infra-Krol groups.

Within the limits of Assam there appears to be no record of any discovery of lead ore, but there is undoubted ground for believing that considerable deposits must exist at no great distance beyond its frontiers. Lead ores occur in numerous localities in British Burma, but little is known either of the nature or the extent of the deposits. Native Burma and the surrounding states are believed to produce large quantities of lead. In Tenasserim lead ore is said to occur in limestone of Carboniferous age. The exact character of these deposits does not appear to have been placed on record, but there would seem to have been some crude attempts made to work a few of them.

COPPER.—The copper ores of Peninsular India occur in the older crystalline or metamorphic rocks, as well as in various groups of transition age. In Extra-Peninsular India they are found, for the most part, in highly metamorphosed rocks, the precise relations of which to those of the Peninsula have not in all cases been determined. As a rule, to which there are but few exceptions, the copper ores of India do not occur in true lodes, but are either sparsely disseminated through the rocks which contain them or are locally concentrated in patches and bunches; occasionally also fissures have by infiltration become filled with ores, and veins on a small scale have thus been produced. Both in the Peninsular and Extra-Peninsular regions there are ancient mines of great extent whose history is lost in remote antiquity, but working for copper ores is now carried on only on the most limited scale.

In the Madras Presidency traces of copper in greater or less abundance are found in Trichinopoli, Bellary, Kadapah, Karnul, and Nellore. Some of the most extensive copper mines of this part of India are situated in the Nellore district, in the vicinity of the villages of Gunnipenta and Yerrapilly. The natives of the locality attribute the working of the earliest mines to the kings of Bijanagar; and after the fall of the Hindu empire in 1564 it is believed that the Mogul conquerors and the agents of Tipu and Hyder successively carried on mining operations. The excavations are described as being of great magnitude, and extensive mounds of copper slags testify to the fact of large quantities of ore having been smelted upon the spot. The principal ancient mines are thirty miles north of Yerrapilly, in the neighbourhood of Gorganpully; they are said to be 100 feet in depth, and to extend over a length of several hundred feet. The Nawab of the Carnatic is stated to have worked mines in the Venkatagiri taluk previous to the year 1780, and that they were only given up on the assumption of the country by the British. The first attempt to work the mines of this locality by Europeans was made in 1803, since which time operations have, at various periods, been resumed; but on each occasion the workings resulted in pecuniary loss. The information which is possessed relative to the nature and extent of these deposits is far from complete, although it is certain that very rich copper ores have been obtained from the mines.

In Bengal at Bairuki, in the Deoghur district, copper ore was discovered by a native in the year 1849. The report of this discovery created at the time a good deal of excitement, although it does not appear that a company for working the mine was ever formed. Mr. Barratt, an English mine agent, however, reported favourably on the property, stating that the ore occurred in a champion lode 9 feet thick. In the Singhbhum district, and in the State of Dhalbhum, are probably the most widely extended copper deposits known in Peninsular India. Traces of copper ores usually marked by the presence of ancient excavations, here extend at intervals over a distance of about seventy-six miles. The copper ores appear to exist on a well-defined horizon close to the base of the transition system of rocks. As a rule the ores are disseminated through bands of schist, the dip of which corresponds to that of the adjacent strata; in some places, however, they would seem to occur in more or less regular veins. Indications exist of mining and smelting having been carried on in this region from a very early period, the available evidence pointing to the Seraks being probably the first to inaugurate working in this locality. The number and extent of the ancient workings testify to the assiduity with which every trace of ore was followed both by the early pioneers and subsequently by those who followed them in more recent times. Mining under European management was commenced at Landu and Jamjura in 1857, and for a short period from 60 to 65 tons weight of copper ore was turned out monthly; but either from injudicious expenditure, or through the poverty of the deposit, operations were abandoned in 1859.

The excavations which mark the position of the ancient workings at Baragunda in the Hazaribagh district, are situated along a line of outcrop of metamorphic rocks, which form a ridge three-fourths of a mile long between the villages of Parsabera and Baragunda. These rocks consist of quartzite and granulite gradually passing into gneiss, associated with micaceous talcose and hornblendic schists. The excavations at this place are very extensive, but nothing is known either as to their date or origin. Although some of the specimens obtained from this locality show that in many cases the ore occurs as a constituent of the schists, others would apparently indicate the presence of segregations parallel to the bedding. Dr. McClelland mentions the occurrence of large quantities of copper slags, covering several acres of ground, at the village of Giridi, about two miles distant from the mines; where, in the vicinity of fuel and water, the ores were evidently smelted.

In the Central Provinces copper ores are known to exist in

Raipur, at Chicholi; in Jabalpur, at Sleemanabad; Narsinghpur, at the Birman Ghât; and in Chanda, near Thana Wasa. At the Birman Ghât, in the Narsinghpur district, copper ores were discovered in the year 1873 on a small island in the bed of the Narbada river. Mining operations were commenced shortly afterwards, and a parcel of ore which was sent to England for sale is reported to have paid its expenses. Shortly after the ground was first opened the band of metalliferous rock was stated to have a thickness of 6 feet. The results of subsequent operations are not recorded, but the mine was ultimately abandoned.

Copper ores are found in several of the independent states of Rajputana, as well as in the British district of Ajmir. In these regions mining was formerly carried on upon a very extensive scale, but at present the business of the miner has become all but extinct, since operations are carried on in but few localities, and always upon the most limited scale. Mines occur in the States of Alwar, Bhartpur, Jaipur, Udepur, Bundi, and Bikanir. At Daribo, in the Alwar State, there are mines situated on a sharp anticlinal curve in a thin band of black slates intercalated in quartzites. There appears to be no true lode at this place, and the ore, which is copper pyrites mixed with mispickel, occurs irregularly disseminated through nearly black slates; nests of ore being also occasionally met with. The ore as is usual by the native process, is pounded, made into balls with cow-dung, roasted, smelted with charcoal, and afterwards refined in an open fire. During the last twelve years the average annual yield of this locality has only amounted to 3 tons 8 cwts., and this, owing to the influx of European copper, is gradually diminishing. Small quantities of the sulphates of copper and iron are obtained by washing the mine refuse. At Singhana, in the Jaipur State, the mines are described as consisting of tortuous galleries of great extent. At the working face fires were lighted, which caused the rock to split up, and the loosened fragments were subsequently detached by the aid of wedges. The principal entrance to the mine is by a gallery driven into a ridge of quartzite in the direction of its strike, and at a point several hundred feet above the level of the plain. This gallery is sometimes 60 feet in width, is of considerable height, and from it three separate galleries strike off into the hill. In these there is scarcely a trace of ore remaining, and all the ends are concealed by fallen *débris* or by accumulations of water. These mines have long since been abandoned on account of their general poverty, but considerable quantities of blue vitriol, alum, and copperas are still manufactured from decomposed slate and other refuse from the old workings. At Khetri there are workings very similar to those of Singhana. The ores are here sold by auction to Mohammedan merchants, by whom they are smelted in small blast furnaces blown by hand bellows; the manufacture of blue vitriol, copperas, and alum, is actively carried on at these mines.

According to Mr. Ball, there is no authentic information with regard to the existence of copper mines either in Bombay or in Balochistan, but in Afghanistan a copper-producing district is known to exist between Kabul and Kuram. In the Punjab, copper deposits are by no means numerous, and none of them possess any particular importance.

In the North-West Provinces, the districts of Kumaun and Garhwal have long attracted attention through their copper mines. These were first examined by a Cornish miner so long ago as 1838, and were subsequently worked at various times until the year 1855, when they were visited by Mr. W. J. Henwood, who came to India for the purpose of examining and reporting upon the metalliferous deposits of Kumaun and Garhwal. Mr. Henwood's report deals principally with the iron ores of the country, but he also devotes several pages to copper deposits, with which he was not, on the whole, favourably impressed.

The district in which the Sira mines are situated consists, for the most part, of clay slate, in which traces of copper are numerous. Several neighbouring deposits have, from time to time, been examined, but mining operations of any extent have been confined to one only, in which copper ores occur in a stratum parallel to the bedding of the adjoining rocks. The ore-producing floor is from two to three feet in thickness, but is at intervals enlarged by the falling into it of metalliferous strings of quartz. Its principal constituents are quartz and talc, but the former, frequently mixed with a little calcite, is by far the more abundant ingredient. Although sometimes accompanied by iron pyrites, chalcopyrite is the most plentiful ore, and occurs in the form of short narrow veins, small bunches, and scattered granules. In the richest portions of the deposit it is, however, very thinly distributed throughout the matrix.

The Danda Mine is situated near the top of a rugged and precipitous mountain, the ridge of which is talcose slate, and the middle chloritic slate, while the base is composed of a mixture of the two rocks in thin alternate layers. The chloritic slate is at intervals interstratified with thin lenticular beds of quartz, few of which exceed three feet in length or are more than six inches in thickness. Occasionally chlorite is, to some extent, diffused through this quartz, which is also sparingly mingled with iron pyrites and chalcopyrite. Fig. 78, after W. J. Henwood, represents a section at the Danda Mine, in which A is talcose slate, B chloritic slate, *a* the metalliferous quartz, and *b* joints.

At Dhanpur or Dhunpoore the slate rock of the neighbourhood, which is generally blue, although sometimes buff or brownish in colour, has usually a silky lustre, and is much contorted by the intercalation of thin crooked and irregular beds of quartz. The quartz is almost invariably associated with a small proportion of calcite. A bed of siliceous limestone, of which the prevailing colour is a pale buff, and which, though slightly undulating, may

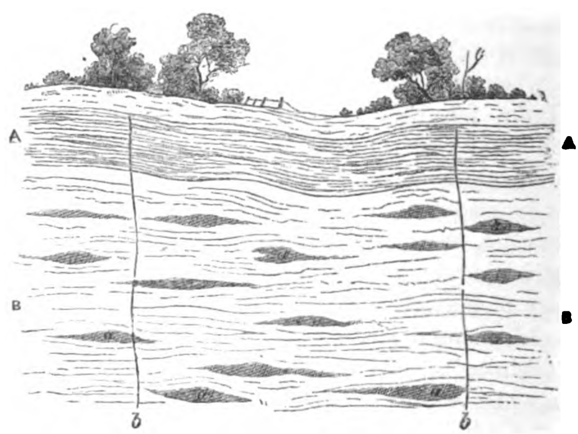

FIG. 78.—Danda Mine; section.

be regarded as nearly horizontal, is usually about one foot in thickness, but occasionally enlarges to fifteen or even twenty feet. The slate and limestone are both traversed by two sets of joints; one nearly parallel to the strike, and bearing E. and W., and the other between N. and S. and 10° to 15° E. of N. and W. of S. Each series is highly inclined, and in both dip and bearing is subject to frequent but inconsiderable flexures. In the majority of cases these joints exhibit mere contact surfaces; sometimes, however, they enclose laminæ of the adjoining rock, or plates of erubescite, while in others they contain a mixture of copper ore and country rock. The non-metalliferous material thus included is divided into approximately lenticular masses by the reticulation of numerous small joints, which are often faced with clay. At these intersections the surfaces of the lenticules of sterile matter, as well as those of the ore itself, are often marked by slickensides. A third set of joints, which bears about 30° E. of S. and W. of N., is but imperfectly developed. The joints of both the principal series widen, and become more metalliferous, in proportion as they approach the nearly horizontal bed of siliceous limestone, and then sometimes attain a thickness of above six inches. These characteristic deposits of ore do not, however, occur when the two systems of transverse joints and the nearly perpendicular ones merely intersect one another, but at those points only where the intersections come in contact with the upper surface of the bed of limestone.

The rock in the vicinity of these double intersections is often for some distance richly charged with nests of erubescite and copper pyrites, from which veins branch off and penetrate both the limestone and the adjoining slate. In extreme cases this impregnation of the rocks extends for a distance of from twenty-five to thirty feet, but generally for less than half that distance. Fig. 37, page 92, after Henwood, shows the mode of occurrence of copper ores in the rock joints at this mine. The report of Mr. Henwood on the Chaumattiya Mine clearly indicates the general mode of occurrence of copper ores throughout the region. He says: "There is no *lode* or metalliferous *vein* visible in it, nor have we seen one during our enquiries in this country." [1]

The existence of copper ores in Darjiling was first discovered in 1854, since which time its occurrence in various parts of the district has been established. A mine which was opened about 1870 at Mangphu, on the Tista, is considered the best in Darjiling, and is believed to be the only one at present in operation. The rock is a light green slate, containing irregular layers of slaty sandstone. The ore, with which there is but little iron pyrites, occurs in both rocks, in the form of lenticular beds. The cupriferous layers occur at intervals throughout a total thickness of 200 feet, and openings have been made upon them at various levels.

No copper ores have hitherto been discovered either in Assam or in British Burma. In Tenasserim specimens of an ore containing copper were obtained in 1863 at a point on the Yoonzalem River; some copper slags were also found in three different localities; but at the present time no copper industry of any kind is carried on in the country.

TIN, &c.—Tinstone has been rarely found within the limits of Peninsular India, and the only localities in Extra-Peninsular India

[1] "Selections from Records, Government of India," vol. viii. 1855, p. 4.

where it occurs in any considerable quantities, are situated in the Tenasserim division of British Burma.

In the Bengal Presidency tin oxide occurs at Nurunga, and is described as forming lenticular beds in gneiss which are seldom above one foot in width, but are sometimes as much as sixty feet in length. About fifteen years ago from 8 to 9 cwts. of metallic tin were obtained from ore mined at this place.

In Bombay a few specimens of cassiterite of mineralogical interest only, have occasionally been obtained, but as yet there is no reason for supposing that it occurs in quantities possessing any commercial importance.

Tin ore is found in various localities in the Tenasserim division of British Burma, and is collected chiefly by Chinese labour from sands and other alluvial deposits. About the year 1873 the township of Ma-lee-won was leased to Messrs. Steel & Co., a firm of Rangoon merchants, with a view to working for tin upon a large scale. In addition to an abundant supply of stream tin, various rich tin lodes were said to have been discovered. During the year 1874–1875 machinery was erected, roads opened out, and a parcel of ore prepared, which yielded about seven tons of metallic tin. As, however, the outlay had very largely exceeded the returns, the lease was abandoned in 1877.

So far as is yet known, zinc ores are of rare occurrence in Peninsular India, but in some of the Southern Provinces blende and calamine are described as being somewhat more abundant. In Rajputana there is at least one mine, which is reported to have been formerly worked for ores of zinc.

Cobalt ores in small quantities are found in some of the mines of Rajputana, and are used for the purpose of colouring glass bangles; ores of this metal also occur in Tenasserim. Both cobalt and nickel are present in small quantities in the pyrrhotine from the Khetri Mines, and traces of nickel sometimes occur in iron ores from Bhangarh. Ores of manganese have been found in various localities, and some of the Indian iron ores contain a certain amount of that metal.

IRON.—Iron ores are so plentiful over large areas in British India, that it would be impossible within the limits of the present notice to give even the names of the various localities in which they are known to be abundant. In order, therefore, to convey an idea of their abundance and extent, it will be convenient, in the first place, to give a concise account of their mode of occurrence and distribution in rocks of various ages, and, subsequently, a short description of a few of the most important deposits hitherto discovered. In Peninsular India the magnetic oxide occurs either in beds or veins in almost every region in which metamorphic rocks prevail; while in certain localities, as in the Salem district in the Madras Presidency, the development of magnetite is on a scale of extraordinary magnitude, whole ranges being composed of this mineral in its purest condition. In many cases these deposits would appear not to be in the form of veins, but to occur as beds, in the same way as do the gneissoid and schistose rocks with which they are associated. In the Chanda district enormous deposits of specular iron ore and magnetite occur under similar circumstances. Mr. Ball remarks with regard to the iron ores of India: "To the abundance and wide-spread distribution of these ores in the oldest rocks is no doubt to be attributed the fact of the frequent recurrence of considerable deposits, and the general dissemination of ferruginous matter, which more or less characterise the sedimentary rocks of all subsequent periods."[1]

Bedded magnetite is likewise known to occur in the sub-metamorphic or transition rocks; while, both in the metamorphic and sub-metamorphic series, considerable veins of limonite are found in fissures and along lines of fault. Examples of such deposits occur in Kadapah, Karnul, Manbhum, Jabalpur, &c., &c.; but the rich ores of Central India occur principally as hæmatites, in rocks belonging to the lower transition series.

In the Gondwana system of rocks, although many of the conglomerates, sandstones, and shales of the Barakar group are almost free from iron, others enclose concretionary masses of limonite; while in some of the coal-fields bedded clay ironstone occurs in sufficient quantity to render them of considerable importance. It is believed that in all the coal-fields these ores, whether of a concretionary or bedded character, are used by the native smelters, but they invariably select the unaltered carbonates only, as they regard ores which have been partially transformed into limonite as unsuitable for reduction. The so-called Ironstone Shales are not represented beyond the limits of the Damuda Valley, and as a source of iron ore their development is at its maximum in the Raniganj coal-field, where there is an inexhaustible supply of readily accessible ore. This mineral, which originally existed either as blackband or as clay ironstone, has, near the surface been to some extent altered into limonite. In the Raniganj-Kamthi group the distribution of iron ore is very unequal, since

[1] "Geology of India," vol. iii. p. 335.

in the typical Raniganj rocks ferruginous matter is often almost wholly absent; while in their western equivalent, the Kamthi group, there is not only much disseminated oxide of iron, but also thin layers of iron ore which are made use of by the natives for smelting purposes.

The characteristics of the succeeding groups of the Gondwana series, so far as iron ores are concerned, are almost precisely similar to those last described. The Cretaceous rocks are next in sequence in the peninsular formation. In the Trichinopoli district of Southern India, rocks of this age contain nodules of iron ore in considerable abundance, and, when fuel was locally more abundant than it is at present, they were, to some extent, smelted by the inhabitants.

The Deccan trap, which is believed to have been poured forth towards the close of the Cretaceous period, and was perhaps continued into early Tertiary times, contains large quantities of iron ore. This, to a large extent, occurs in the form of disseminated crystals of magnetite, but occasionally also either as nests or layers of hæmatite, gradually passing into bole or ferruginous clay. The beds of rivers traversing this trap contain iron sands, and these, after concentration by washing, often supply the small blast furnaces of the native iron-smelter.

Segregated bands of iron ore, which not unfrequently occur towards the base of certain beds of laterite, are the sources of an easily worked brown hæmatite which sometimes contains a large percentage of iron. These ores have been employed by native smelters in localities scattered over almost the whole of India, while at Bepur in Malabar, and at Mahomed Bazaar in Birbhum, the same ores have been smelted at establishments under British management.

In addition to the foregoing there are detrital ores of sub-recent age, resulting from the breaking up and re-arrangement of the older deposits, as well as from other superficial accumulations of ferruginous material. These, being generally obtainable without much trouble, are frequently preferred by the natives to harder or more refractory ores.

In Extra-Peninsular India iron ores are found in considerable abundance in groups of rocks, many of which are of very different ages from those which occur within the limits of the peninsula. The principal sources of these are Tertiary rocks; but in the North-western Himalayas, and it is believed also in Afghanistan and Burma, there are considerable deposits of iron ore in the older metamorphic rocks.

In the Madras Presidency, iron ores are said to be very generally distributed throughout the Madura district, and, according to Mr. R. B. Foote,[1] ores obtained from lateritic conglomerates were formerly smelted, of which large heaps of slags scattered plentifully over the country afford evidence; the industry is, however, now extinct. In this district, a deposit of magnetic iron ore occurs in gneissic rocks about a mile north-east of the village of Mallampatti, in the Pudokotai State. Mr. Blanford,[2] in his description of the Cretaceous rocks of Trichinopoli, mentions that they frequently contain nodules of iron ore, which were formerly smelted, as is evidenced by numerous mounds of slag; but owing to the scarcity of timber the industry is now almost, if not entirely, extinct. The extent, number, and thickness of the beds of magnetic iron ores in the Salem district, is among the most remarkable phenomena connected with the geology of India. Messrs. W. King and R. B. Foote, who have given an account of the distribution of these ores, have divided them into the following groups :—[3]

1st. The Godumullay group, east and north-east of Salem.
2nd. The Tullamullay-Kolymullay group.
3rd. The Singiputtay group.
4th. The Tirtamullay group.
5th. The Kunjamullay group.

On account of the persistence of these beds over long distances, they frequently afford a valuable clue to the geological structure of large areas. They, in some cases, form the culminating ridges of high ranges of hills, and are occasionally from 50 to 100 feet in thickness. Where, therefore, such beds are either vertical or steeply inclined, enormous amounts of ore are laid bare in cliffs and escarpments. The purity of this ore varies considerably, being sometimes much mixed with quartz, but ore of the best quality is, nevertheless, to be obtained in quantities which can only be estimated in thousands of millions of tons. The "Porto Novo Steel and Iron Works," which, in 1833, were established in South Arcot, were, up to the time of their suspension, supplied with ores from Salem. The same company appear to have also established works at Bepur. How long they continued in operation is not known, but they appear to have fallen into the hands of a succession of companies, and the ore is believed to have been derived from the laterite. In 1861 puddling was superseded by the introduction of a Bessemer

[1] *Records Geol. Surv. Ind.*, vol. xii. 1879, p. 147.
[2] *Mem. Geol. Surv. Ind.*, vol. iv. 1865, p. 216.
[3] *Ibid.*, vol. iv. 1865, p. 58.

converter, which does not seem to have been a success, as the works have been closed for some years. In the Kadapah and Karnul districts, Madras, iron ores occur in great abundance, and are treated at a number of native iron-smelting villages situated along the eastern side of the Khundair Valley. Certain tracts in Hyderabad or the Nizam's Territory have long been celebrated for their iron ores, as well as for the good quality of the metal produced from them. In the Orissa Tributary States the manufacture of iron is carried on upon a very small scale, and by an extremely rude process.

In the Birbhum district in Bengal, where attempts, extending from 1777 to 1878, have been unsuccessfully made to introduce the European system of iron mining, the ores are described as being partly earthy and partly magnetic oxides of iron, which occur disseminated in a soapy trappean clay found in beds towards the base of the laterite.

Notwithstanding the abundance of iron ore throughout Sambalpur, Rehrakol is the only locality in which smelting is extensively carried on by the natives. In the Jabalpur district iron ores occur under four distinct conditions, namely, as detrital accumulations, in the Gondwalla sandstones, in sub-metamorphic rocks, and as accumulations in fissures and along lines of fault. In the Narsinghpur district, the ores of Omarpani have long attracted attention on account of the excellent quality of the iron manufactured from them. These ores are associated with quartzites and limestones, but their precise mode of occurrence is somewhat obscure. The iron ores of the Chanda district are extraordinarily rich and abundant, and comprehend magnetite, hæmatite, and various lateritic ores.

Among the most important deposits of iron ore in Central India are those of the Gwalior State, which include magnetite and red and brown hæmatites, which were once somewhat extensively worked by the natives, but are now, to a great extent, neglected, in consequence of the great distances the ore has to be carried to the fuel. Large deposits of iron ores occur in numerous other localities in Central India, but in one only, namely, at Barwai, does any attempt appear to have been made to introduce European processes of manufacture. The ore is chiefly limonite occurring in irregular masses, but hæmatite is also found in the neighbourhood. In the year 1861 the erection of all the plant necessary for the production of charcoal iron was commenced in this locality by Mr. Mitander, a Swedish metallurgist, but the works were never completed, and, consequently, no iron was produced.

Throughout the Presidency of Bombay iron ores occur in the form of magnetite, hæmatite, and limonite. These ores are all more or less extensively worked in native forges, but we have but little information with regard to their respective modes of occurrence. Although the celebrated Delhi pillar, which is unquestionably the finest known example of Indian metallurgical art, is within the limits of the Punjab, this province is no longer remarkable for its manufacture of iron. The iron ores of the Raniganj field, Bengal, all occur in the ironstone shale which intervenes between the coal-bearing groups of Raniganj and Barakar in the Damuda series.[1] These ironstone shales are traceable at the surface for a distance of several miles, the total thickness of the group being estimated at 1,400 feet. The ore does not occur throughout, but is most abundant towards the top and bottom, where it is found in bands, lenticular masses, or as strings of nodules. It is usually a clay ironstone somewhat altered near the surface, but in some places a regular blackband ironstone has been met with. It is easily obtained at shallow depths, and for a long time no regular mining would be necessary. During the last fifty years propositions have at various times been made to start the manufacture of iron upon a large scale in this locality. The matter was not, however, seriously taken up until 1874, when the "Bengal Iron Company" was formed; but in 1879 it ceased operations. The cause of this non-success is attributed, in the first place, to the insufficiency of the original capital, and, in the second, to a heavy and unexpected charge which was made for the land taken up by the company. The ore, which is of good quality, and contains from 45 to 47 per cent. of metallic iron, was raised and laid down at the furnaces at a cost of about one shilling per ton. From its commencement to the time of its suspension the Bengal Iron Company made 12,700 tons of pig iron, the rate of production being about twenty tons daily. Iron ores occur in the Manbhum, Singbhum, and Harazibagh districts; in the latter the crystalline and metamorphic rocks, said to contain large quantities of magnetite and other ores of iron, were, a few years since, examined by Messrs. Bauerman and Ball, who were of opinion that the accounts previously given with regard to its quantity had been considerably exaggerated. In the sub-division of Palamow, iron ore occurs in well-defined zones of ferruginous slates 200 feet in thickness, of which about 10 per cent. may be regarded as of workable quality.

[1] W. T. Blanford, *Mem. Geol. Surv. Ind.*, vol. iii. 1865, p. 191.

In the North West Provinces the existence of rich iron ores in Kumaun was first noticed in the year 1850, and in 1855 Mr. W. J. Henwood was commissioned to visit India and to examine and report upon the iron and copper ores of Kumaun. This report was not favourable to the views previously expressed with regard to iron-smelting upon the plains, and Burrulgaon was consequently selected as the site for an experimental blast furnace. The results obtained were regarded as unsatisfactory, but, nevertheless, with a view of demonstrating the possibility of successfully manufacturing iron upon a large scale in India, the Government in 1857 erected new works at Dechauri, and at the same time a commercial undertaking also commenced operations under the title of "Davies and Co." In 1860 the Government, having become dissatisfied with the results, sold the works, which were bought on behalf of a company which in 1862 became amalgamated with Davies and Co., under the name of the "North Indian Kamaun Iron Works Company, Limited," and in 1864 suspended operations. In 1874 Mr. H. Bauerman visited Kamaun and reported with regard to the advisability of re-establishing the manufacture of iron, but his opinion was unfavourable to the project. This view of the question not having been acceptable to the local authorities, a report was called for from the Geological Survey, and in 1877 the Government again embarked in the manufacture of iron. In 1879 the works were still in operation, but with unsatisfactory results. The fuel employed was charcoal, and the ores specular and micaceous hæmatite from Ramgarh, occurring in crystalline schist, hæmatites from small veins in quartzite in Kharina, clay ores from Kaladhungi, and siliceous brown hæmatites from Dechauri. These ores, all of which are more or less siliceous, contain from ·11 to 1·67 per cent. of phosphoric anhydride. Of these localities the first two are in the heart of the mountains at some considerable distance from the furnaces, while the other two are immediately adjacent to them. Although called clay ironstones and siliceous hæmatites, they are actually concretionary limonites of very inferior quality, often containing more sand than iron ore. Throughout India the ores of the crystalline rocks are extraordinarily pure, while those of the sedimentary deposits are lean and contain phosphorus.

In Assam, the principal ores found in the valley of the Brahmaputra are clay ironstones of the Coal-measures, and an impure limonite from the Sub-Himalayan strata. Ball states that the only iron ore worked in the native furnaces of the Khasi and

Jaintia hills is a titaniferous magnetic oxide, procured by washing ferruginous earths and gravels.

In the Pegu division of Burma, an abundant supply of iron ore is found in the Tertiary rocks of the Eastern Prome district. In Tenasserim, seventeen distinct localities are known in which there are deposits of iron ore, all being situated in the Tertiary hills between Maulmain and Tavoy.

STRAITS SETTLEMENTS.

These settlements, so-called from their situation in the Straits of Malacca, comprise Singapore, Penang, Province Wellesley, and Malacca, and in connection with them are the protected Native States of Perak, Salangore, and Sungei Ujong.[1] Travellers have at all times celebrated the metallic riches of the Malayan archipelago, and ancient historians speak of an active commerce existing long before the Christian era between India and the western countries of Arabia, Egypt, Greece, &c. The Peninsula of Malacca was not less celebrated for its mineral riches, as it figures on the maps of Strabo and Ptolemy under the significant name of the Golden Chersonese. In the sixteenth century Malacca was the most important centre of Further India, gold and tin being then the object of an important trade. Tin appears to have been for a long period produced in the State of Perak, since all travellers agree upon this point. Godinho de Eredia, at the beginning of the seventeenth century, states that the country of Viontana, now called Sungei Ujong, produced gold, silver, mercury, tin, and large quantities of iron.

The celebrated French traveller Tavernier (1677) states that the money in Queda and Perak was made of tin; this coin weighed 1½ oz. and passed for two "sols." The value of tin in Perak must consequently have been about 2,200 francs or £88 per tonne. The mines of which Tavernier speaks, soon, however, acquired a considerable extension, as the king did not long content himself with working the tin for coinage, but also produced it for exportation.

The geological characteristics of the Peninsula of Malacca are as yet but little known, owing to the difficulty of access to the interior and to the dense vegetation which there prevails. The mountains are generally composed of granite, which is

[1] M. J. Errington de la Croix, "Les Mines d'Étain de Pérak" Paris, 1882.

traversed by quartz veins containing tin; iron ore also occurs in large irregular masses, but at present is not worked. The quartz veins contain tin ore associated with iron oxide, and sometimes with gold. The tin ore of Perak is cassiterite generally of a brown colour, but in some districts it is white, grey, or pink, and is often translucent. The lodes occur under the same conditions as in Cornwall, and in some districts they must have attained a considerable thickness, judging from the enormous alluvial blocks of massive ore which are sometimes found. The ore is never obtained from mines, the alluvial detritus only being washed in stream-works; the ore is exceptionally pure, and contains no sulphur, arsenic, or wolfram.

The production of tin has for several years constantly increased, which sufficiently proves the progress of mining in Perak.

The exportation for five recent years was as follows:—

Year.	Larout.	Lower Perak.	Total.
	Tonnes.	Tonnes.	Tonnes.
1876	1,783	271	2,054
1877	2,511	547	3,058
1878	2,895	739	3,634
1879	3,478	848	4,326
1880	4,406	1,038	5,444

The production of tin in 1880 amounted to 5,444 tons, of the aggregate value of £450,000. The exports of metallic tin from Perak in 1882 amounted to 7,000 tons, and about 40,000 Chinamen were employed. Penang not only receives the entire production of Perak, but also the tin produced in Siam and its dependencies which occupy the western side of the peninsula. This mportation amounted in 1879 to 8,803 tonn; a quantity approaching the total production of Cornwall. The total amount of tin exported from Penang and Singapore in 1882 was 15,942 tons.[1]

DUTCH EAST INDIES, &c.

Holland produces no valuable metallic minerals, but the Dutch possessions in the East Indies furnish an important supply of tin.[2]

[1] "Mineral Statistics for the year 1882," p. 124.
[2] Everwyn, *Jaarb. Mynwesen Ned. Oost. Indie*, vol. ii. 1872, p. 83.

The island of Banca may be regarded as a continuation of the mountain chain of Malacca, exhibiting similar geological characteristics, and possessing the same riches in tin streams. This island contains several large masses of coarse-grained granite, in which veins of porphyry and finely granular granite are met with. These granitic bosses are surrounded by slates and sandstones of Silurian age, in which tin ore is sometimes found in pockets occurring between the planes of stratification. The ore is mainly, however, obtained from streamworks, and is smelted upon the spot by Chinese labour. Like Banca, the island of Billiton consists of granitic masses surrounded by Silurian slates and quartzites. In 1882 Banca and Billiton together produced 8,550 tons of metallic tin, Banca alone yielding 4,327 tons.[1] Part of this tin goes to China and India, but that destined for Europe is sold by auction at Rotterdam and Amsterdam.

BORNEO.—The metallic and metalliferous productions of Borneo include gold and platinum as well as ores of quicksilver, copper, iron, tin, and antimony. Sambas, Laudak, Montrado, and Borneo proper, furnish the greater proportion of the gold. The auriferous beds consist of coarse sands and gravels, often overlying beds of clay. The annual amount of gold collected cannot be ascertained, but the export from Brunai in 1880 was of the value of $3,663.

Borneo also supplies a certain amount of platinum, which occurs at the south-eastern extremity of the island, where the rocks chiefly consist of serpentine, diorite, and gabbro, covered by a deposit of clay fifteen feet in thickness, under which is an auriferous bed containing magnetic iron sand, platinum, and iridosmine.

Antimony was discovered in Borneo in 1825. The chief mine is at Bidi in Sarawak, and in 1880 antimony to the value of $72,516 was exported. During the same year the export of quicksilver amounted to $66,300. Sumatra, Celebes, and the Philippine Islands furnish considerable amounts of gold.

JAPAN.

The earliest accounts we have of Japan[2] represent that country as possessing great metallic wealth. Marco Polo tells remarkable

[1] *Mineral Statistics for the year* 1882, p. 124.
[2] H. S. Munroe, "The Mineral Wealth of Japan," *Trans. Amer. Inst. Mining Engineers*, vol. v. 1877, p. 236.

stories about the gold in "Zipangu." Kæmpfer, in 1727, speaks of the mineral wealth of Japan, and especially of the abundance of gold. While the Portuguese and Dutch had trading stations in the country, it furnished tangible evidence of the truth of these early reports. Between 1550 and 1639 the Portuguese merchants sent home nearly $300,000 000 worth of bullion, chiefly gold. After the Portuguese, the Dutch continued this trade, and between 1649 and 1671 sent home over $200,000,000 in bullion, of which, however, nearly two-thirds was silver. In 1671 the Japanese Government issued an edict stopping this commerce. Between 1609 and 1858, about 280,000 tons of copper were exported by the Dutch, and 250,000 tons by Chinese merchants. Kæmpfer, in 1727, enumerates iron and tin, in addition to gold, silver, and copper, as products of Japan.

Of all the metalliferous minerals, the ores of iron are the most abundant, and nearly all the different varieties are represented in Japan; but magnetite and magnetic iron sand are probably the most important. In 1874 more than 400 washings for iron sand were in active operation.

Copper is comparatively plentiful, but although it has been mined, to some extent, for nearly twelve centuries, the active working of the mines dates no farther back than about 300 years. The average annual production during the past 250 years has been about 2,800 tons; in 1830 it was 4,000 tons, and in 1874 3,360 tons. This represents the united product of about 200 different mines, but, among these, four only furnish about one-half the total amount. Copper ores occur in veins which are sometimes true fissures, but more frequently they are of limited extent and are apparently irregular deposits. In both cases there is usually a certain parallelism between the different veins in the same region.

The deposits of lead ore in Japan are neither numerous nor particularly valuable. Galena occurs in veins associated with ores of copper and silver; in 1874 thirty-five mines produced 207 tons of lead, more than half of which was the yield of a single mine. Of the remaining mines probably two-thirds yielded less than a ton each.

Tin ore occurs only in veins, although it has been stated that deposits of stream tin have also been discovered. Nearly all the tin produced in Japan comes from the Taniyama Mine, where there are 21 distinct veins, averaging eighteen inches in thickness. These traverse sedimentary rocks composed of soft tuffs, shales, and sandstones, with occasional beds of hard, dark blue quartzite.

The surface is almost everywhere covered with a deposit of modern pumice, and exposures of volcanic rock are common. The veins course from north-west to south-east; the strike of the rocks is from north-east to south-west, and the ore, which is cassiterite, is enclosed in a quartzose gangue. One hundred and twenty persons are employed, and the annual production is about eight tons.

In 1874, four mines were producing antimony, but only on a very small scale. Cinnabar occurs in two localities, as impregnations in the sandstones of the Coal-measures.

The silver-bearing veins are, as a rule, true lodes, continuous in depth, regular and persistent. In 1874, ninety-eight mines produced 312,000 oz. of silver, of which one-half was the yield of ten mines. Silver occurs associated with copper and lead ores, and sometimes also with gold. Native silver, argentite, and antimonial silver ore, are the only true silver ores found; but this metal likewise occurs in fahlerz, in galena, in copper and iron pyrites, and in blende.

Gold occurs in quartz both in veins and in placer deposits, but the latter are uniformly poor. The principal portion of the gold annually produced comes from mines worked chiefly for silver. Mines producing gold alone are, as a rule, not remunerative.

According to the records of the Japanese Mining Office, there were in 1874 no less than 1,856 productive mines in Japan. The following table gives the production of metals in Japan during the year 1875.

PRODUCTION OF METALS IN JAPAN, DURING THE YEAR 1875.[1]

Metals.	Tonnes.	Kilogr.	£
Iron	1,135	—	10,642
Gold	—	376	51,600
Silver	—	9,700	80,496
Copper	3,045	—	185,760
Lead	188	—	4,391
Tin	7	—	619
Total			333,508

Compared with the reputed yield of the country in Portuguese and Dutch times, the above table shows a considerable falling off,

[1] *Statistique de l'Industrie Minérale en France*, 1882, p. 200.

especially in gold and silver. This is mainly due to the increased value of labour, and to the exhaustion of some of the more easily worked deposits.

THE AUSTRALASIAN COLONIES.

VICTORIA.

The chief metallic product of the colony of Victoria is gold, but both tin and copper ores are successfully mined, while ores of lead, antimony, and iron, likewise occur in considerable abundance.

GOLD.—The gold of Victoria is derived from three distinct sources, namely, from recent alluvium; from deep leads chiefly of Tertiary age; and from quartz veins. The deposits belonging to the first class require no detailed description, and consist of recent drifts, and surface accumulations actually in course of formation.[1]

The older deposits comprehend drifts of Pleistocene, Pliocene, and probably also of Miocene age, but of these the second are the most numerous and productive. Pleistocene deposits generally form the alluvial flats which are found more or less constantly in all the valleys of the gold regions, and through which the streams of the present day have worn their channels. They are composed of gravels, sands, clays, and loams varying in their order of succession, and of which the composition differs in accordance with the nature of the rocks from which they have been derived.

The deeper drifts, chiefly of Pliocene age, have, in many instances, been protected from the action of denudation by a thick covering of basalt. This forms a prominent feature of many of the older leads throughout the colony, as exemplified in the case of the Durham Lead near Ballarat, where the lava has flowed down the course of an ancient valley and covered a river-bed and its accumulated sands and gravels to a depth of nearly 300 feet.

Although a very large proportion of these old river accumulations are of Tertiary age, there would appear to be others still older, even dating from the Carboniferous period.

The quartz reefs of the colony are, for the most part, enclosed in Silurian rocks, which they frequently traverse parallel to their bedding, while in other cases they intersect them independently

[1] Much valuable information relative to the occurrence of gold in this colony has been derived from Mr. R. Brough Smyth's "Gold Fields and Mineral Districts of Victoria." Melbourne, 1869.

of their stratification, and thus become true lodes. Gold is not only found in veins traversing granite and diorite, but is also sometimes disseminated throughout the rocks themselves. It likewise occurs in sandstones, and between the bedding planes of Silurian, Devonian, and other rocks. In veins it is often associated with iron pyrites, galena, and other metallic sulphides, as well as with the oxides of iron and manganese, together with calcite, chalybite, carbonate of manganese, and bitter spar; and, more rarely, heavy spar. Pieces of fossil wood found in the deeper diggings, as well as fragments of mine timbers from some of the older workings in deposits of this class, have, under the microscope, exhibited, distributed throughout their mass, particles of gold associated with iron pyrites.

The principal mining districts of Victoria are Ballarat, Beechworth, Sandhurst, Maryborough, Castlemaine, Ararat, and Gippsland. In the early days of gold mining in Australia, prior to the discovery of deep leads, and before the working of quartz reefs was begun, the miner was content to wash the sands brought down by rivulets, the soil lying on the slopes of hills, or gold-bearing strata accumulated in valleys. From these sources has been derived a by no means inconsiderable proportion of the gold produced in Victoria.

The principal gold-fields of the mining district of Ballarat are Ballarat, Buninyong, Creswick, Clunes, Smythesdale, Blackwood, Steiglitz, and Gordon; at all which places rich surface gravels and shallow deposits have been found. The shallow diggings at Buninyong and Smythesdale, like those of Ballarat, were once remarkable for the wealth obtained from shallow gullies and from the surface of the hills. At Creswick the shallow alluvium was in many places very rich, and shortly after the field was first opened a party of miners took 145 oz. of gold from the bottom of their shaft; and where a rich patch was struck it was by no means uncommon to see 12 oz. washed out of one tubful of dirt. The Blackwood gold-fields are situated on the upper tributaries of the Lerderderg River, which have cut deeply into the schists forming their beds. This gold-field offered peculiar facilities to miners with limited capital, inasmuch as no deep sinking was required, nor was any machinery for lifting water necessary, since there is in every part an ample fall for the drainage. The Steiglitz gold-field is situated on the upper waters of Sutherland's Creek, a tributary of the Moorabool River. When these diggings were first opened, about the year 1855, one miner, assisted by a boy, is said to have collected gold to the value of £100 in one month, and nuggets of ten ounces and above were sometimes met with. Gold is found in every part of the Ballarat district where Palæozoic rocks come to the surface.

The principal mining localities of the district of Beechworth are Beechworth, Yackandandah, Chiltren, Wahgunyah, the Upper Ovens, Morse's Creek, Omeo, Wood's Point, Maindample, Alexandra, and Ghin Ghin. This is an interesting district, since it not only contains shallow alluvium, deep leads, and rich quartz veins, but also yields stream tin, and various other minerals, including, occasionally, the diamond. The Beechworth and Yackandandah gold-fields lie within a network of ranges some twenty miles south of the river Murray, and comprehend many tributaries of Kiewa Creek and the Ovens River. In some places masses of granite protrude above the surface, and the detritus of sedimentary strata appears to have been left in basin-like depressions in the granite. Tin ore is found in many places, and in Serpentine Creek the black sand, which is in the proportion of a pound to a panful of dirt, yields gold at the rate of two ounces per ton. The Ovens River is everywhere auriferous; the bed-rock is generally very uneven, and consists of soft yellow sandstone interstratified with hard blue slates. In the Morse's Creek gold-field some very rich claims have been worked. One, taken up by a company of six men, yielded for some time from 60 to 150 oz. of gold per week; and near Harrietville the miners found gold in the ranges at heights varying from 40 to 100 feet above the level of the streams.

The Wood's Point gold-field lies on the northern slopes of the great dividing range which separates the Gippsland waters from those of the Murray district. The formation is schistose, and the rocks, which are usually of Upper Silurian age, are remarkable for being traversed by eruptive dykes and metalliferous veins. Sometimes, although rarely, the gold lies either in a thin layer of sand or pipeclay, or directly on the surface of the bed-rock. More frequently, however, it is met with in the crevices of the rock itself, which near the surface is often more or less decomposed, and is broken up by the miner to a depth of from 20 inches to 2 feet. Gold is also found in pot-holes; and where these cavities occur, the bed-rock is usually either a hard schist or a somewhat decomposed granite. When the gold is found either on the surface of the bed-rock, or is embedded in pipeclay, the course of the stream is usually across the strike of the rocks, and the gold, with more or less sand, is chiefly found behind a hard bar, such as that seen in

Fig. 79, from *The Gold Fields and Mineral Districts of Victoria*, in which *a* is the surface of the water, *b*, wash composed of large disc-shaped slate pebbles with quartz and a little gold, *c*, bed-rock slate, and *d*, gold associated with sand. In some cases the gold accumulates on one side of a creek, as shown in Fig. 80, in which *a* is the sloping bed-rock of slate, *b*, gold in pipeclay, and *c* ordinary wash consisting of slaty pebbles with fragments of quartz and a little gold. The depth of the wash passed through the

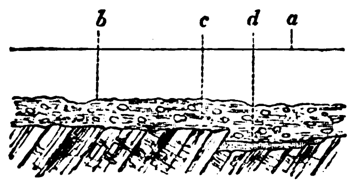

FIG. 79.—Auriferous River-bed; longitudinal section.

washing sluices varies in different localities, and is, to a considerable extent, regulated by the facilities which may be at the command of the miner. Sometimes the whole of the drift, and two feet of the bed-rock, is passed through the washing apparatus, but the gold is chiefly obtained either from the surface of the bed-rock, or from joints in the rock itself.

In the district of Sandhurst, the most important mining localities are Sandhurst, Huntly, Sebastian, Raywood, Kamarooka, Myer's Creek, Bullock Creek, McIvor, Duck Ponds, Redcastle

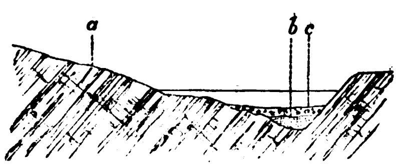

FIG. 80.—Auriferous River-bed; transverse section.

Rushworth, Whroo, Kilmore, Reedy Creek, King Parrot Creek, and Yea. The gold-fields of Sandhurst are situated on the upper part of the Bendigo Creek, which, for a distance of sixteen miles, runs nearly due north, its basin being bounded on the east and west by low schistose hills running north and south. These throw off numerous spurs, some of which are nearly at right angles to the principal range, while others are approximately parallel. Although now more remarkable for the large yield of gold obtained from its quartz veins than for the value of its alluvial deposits, Bendigo at one time attracted thousands of miners to its shallow diggings, and many tons of gold have been obtained from these deposits. The area of this gold-field is about sixteen square miles, nearly one fourth of which is covered by alluvium. Tertiary drifts also occur at Bendigo. The other gold-fields of the Sandhurst district require no special notice.

The mining district of Maryborough comprehends the gold-fields of Maryborough, Amherst, Majorca, Talbot, Avoca, Lamplough, Amphitheatre, Mountain Hut, Peter's, St. Arnaud, Moonambel Red-Bank, Bet-Bet and several others. The Daisy-Flat Lead at Amherst, which is about seven miles in length and at one point nearly a mile in width, had in its neighbourhood very rich patches of shallow alluvium, derived from a series of parallel quartz veins lying to the south-west. Black Creek, which is a tributary of Deep Creek, has been remarkable for its numerous shallow alluviums; and the aggregate length of all its gullies and flats may be taken at nearly twenty miles. The Amphitheatre and Mountain Hut Diggings are on the sources of the Avoca River, and lie immediately north of a basin having the western spur of the great dividing range for its southern rim. This basin is composed of granite, and the dividing ranges follow very closely the boundaries of the formations. At Lamplough the rich ground occurred in patches, and in one case 108 oz. of gold were here obtained from five loads of wash-dirt. The St. Arnaud gold-field is not less remarkable for its steady yield of gold than for the silver found in veins in the neighbourhood. In this district the operations of the miner are frequently impeded from want of the water necessary for washing the auriferous dirt.

The Castlemaine mining district includes the gold-fields of Castlemaine, Fryers' Creek, Taradale, Yandoit, Hepburn, Daylesford, Blue Mountain, Malmsbury, Anderson's Creek, and the Upper Yarra. The greater portion of the gold-field of Castlemaine is occupied by ranges composed of sandstones, mudstones, and slates, which are probably of Silurian age. These rocks are usually not much altered excepting in the immediate vicinity of the granite, where hard fissile slates make their appearance. The strata are everywhere intersected by veins of auriferous quartz, and all the creeks and gullies are filled with recent alluvium, varying in thickness from a few inches to fifty feet. In the vicinity of Red Hill there were four distinct lines of alluvium, the depth at the sides varying from one to six feet, but gradually increasing to fifteen feet to the dip. Here a party of miners took from their claim gold to the value of £30,000, and another found 600 oz. in one pocket; the average yield was about 12 oz. to the tub. Patches of the older drifts occur in many places in Fryers' Creek, but their continuity has been destroyed by denudation. The shallow diggings in this place were once exceedingly rich.

The principal gold-fields of the Ararat district are Ararat, Armstrong's, Great Western, Pleasant Creek, Moyston, Barkly, and Beaufort. The greater portion of this district is occupied by basalt and lavas, but west of Wickliffe there is one isolated patch of the older Palæozoic rocks traversed by quartz reefs. A large tract towards the north is occupied by Upper or Middle Palæozoic rocks. with an exposure of granite east of the Victoria range. Still further westward a large mass of granite rises from the centre of an area of gneiss and mica schists; but no gold appears to have been found within this area. The gold-fields of Ararat proper are situated on the eastern slopes of the Mount Ararat Range, which is a small spur of the Coast Range.

Among the many mining localities of the Gippsland mining district are Jericho, Donnelly's Creek, Stringer's Creek, Fulton's Creek, Hawthorn Creek, Red Hill Diggings, Crossover, &c., including the Wonnongatta, Wentworth, and other rivers with their numerous tributaries. Shallow alluvium containing gold occurs on all the tributaries of the La Trobe, whose sources lie in ranges composed of Palæozoic mudstones and shales, among which numerous small gullies and watercourses have at various times given employment to small parties of miners.

Although the precise horizon of the auriferous Tertiaries of Victoria have not, in all cases, been determined with exactitude, it is notwithstanding believed that those hitherto examined have not often been of Pre-Pliocene age. It is also a generally received opinion that no organisms of marine origin have as yet been found associated with any of the gold-drifts of the colony, and although it has been affirmed that marine fossils have been met with in some of the deep leads at Creswick, the statement appears to require confirmation. Generally speaking, deep leads are so covered by thick deposits of sand and other detrital matter that it is rarely possible, from surface indications only, to determine with any degree of certainty either their true position or their approximate extent. This difficulty is materially increased where deposits of this class, as is frequently the case, have become covered by flows of lava. It is true that leads of this kind usually run nearly parallel to the general direction of the existing streams, but minor deviations from such a course are nevertheless numerous. Their depth from the surface is often considerable, and the cost of drainage great. It likewise frequently happens that a lead which has been rich for a considerable distance suddenly widens and becomes unprofitable to the miner, so that the work of prospecting is both costly and uncertain.

When, as at Ballarat, a lead is covered by a capping of basalt, its course can only be determined accurately by expensive underground workings, or approximately by bore-holes. In the deep workings at Ballarat, as well as in various other gold-fields, large trees are often discovered in the black clays overlying the wash-dirt. Excepting on their outer surfaces, the texture of these trees is scarcely altered, and they are often so well preserved as to admit of being readily carved or made up into furniture. The carbonized appearance of the outside of such trees, is probably due to changes effected by the forces which gradually convert forests into coal-seams. As a means of conveying a distinct idea of the nature of the ground passed through in deep sinkings, the following epitome of an account of the workings of the Great North-West Company at Ballarat may not be without interest.[1]

The surface soil was thin, consisting of a few inches of dark mould covering a stratum of sandy loam, at the base of which were found numerous pebbles of brown iron ore. Between this and the first layer of basalt was a bed of yellow sand, varying in thickness from a few inches to two feet. The first basalt, which in some places cropped out at the surface, was found to be 35 feet in thickness, and between this and the second flow of the same rock there was 11 feet of red clay, intersected by numerous vertical cracks, and containing neither fragments of quartz nor vegetable remains. The second layer of basalt was 144 feet in thickness and was usually compact, but somewhat cavernous towards the top. In sinking the shaft, water in considerable quantities was first encountered at the top of this rock, and when the pumping machinery was stopped it rose to a height of 11 feet above this level. Coloured clays, 28 feet in thickness, containing lignite and occasional fragments of quartz, were found beneath the second basalt; immediately beneath which the clay was nearly black, but at a somewhat greater depth it became brown. Below this brown clay came two feet of white clay mixed

[1] R. Brough Smyth, "The Gold Fields and Mineral Districts of Victoria," p. 147.

with sand and fragments of quartz, covering a seam of compact lignite also two feet in thickness. The colour of the clay beneath the lignite was green. The third layer of basalt, 57 feet in thickness, contained numerous vesicles, and was somewhat columnar in structure.

Beneath the third basalt was a layer of clay about eleven feet thick which at top seemed to be covered with ashes, and on this horizon were found the remains of a large tree. The trunk had the appearance of having been burnt off, while the upper parts had become carbonized, and, when broken, exhibited a glossy fracture like that of charcoal or coal. The roots, which were traced downwards into the clay, showed no indication of the effects of fire, even the smallest rootlets being in a state of remarkable preservation. This clay, excepting quite at the top and towards the bottom, was of a light greenish colour, and was traversed by nearly perpendicular fissures apparently resulting from contraction.

The fourth layer of basaltic rock was struck at a depth of 284 feet, and at the date at which the description was written had been sunk in to a depth of 27 feet. The schistose bed-rock, which had been reached by boring, was found at a depth of 355 feet from the surface, thus showing that the shaft had still to be sunk through a further thickness of 21 feet of basalt and through 23 feet of clay and gravel. The water pumped from deep workings is usually brackish, and is sometimes even decidedly salt.

At Creswick a large tree was found embedded in black clay at a depth of 130 feet from the surface. In these workings the following section was exposed, namely:—

	Feet.
Basalt	100
Sand and gravel	19
Stiff black clay	6
Black drift with fossil tree	5
Total	130

The leaves and trunks of trees, as well as beds of lignite, are of common occurrence in the majority of the deeper drifts of Australia, but they do not appear to have been as yet studied with the amount of attention which could be desired. Some leaves found several years since in the gold drifts beneath the basaltic capping of Table Mountain in California, were submitted to

Dr. Newberry, who described them as closely resembling species found in the later Tertiaries of Europe.[1]

In the neighbourhood of Ballarat, as well as in various other regions in Victoria, the Palæozoic rocks have been subjected to extensive erosion by the action of forces which have at the same time effected the disintegration of the original outcrops of the quartz reefs; and these, having undergone a natural process of grinding and washing, have given rise to the formation of drifts containing a much larger proportion of gold than did the veins from which they were originally derived. When, therefore, quartz reefs are intersected by auriferous leads the wash-dirt is usually, for some distance below the point of their intersection, much richer than elsewhere.

The Duke of Cornwall Company reached the gutter, as the deeper part of a lead is usually called, at a depth of 263 feet 6 inches from the surface, where it was from 60 to 100 feet in width; the thickness of the wash-dirt was about 4 feet, and from about 3,200 cubic feet of stuff 5,000 oz. of gold were obtained.

The section of their shaft is thus given:—

	Ft.	In.
Basaltic rock, including surface soil . . .	35	0
Red clay	7	0
Basaltic rock	113	6
Grey clay	9	0
Drift, gravel, and sand	6	0
Basaltic rock	89	0
Wash-dirt	4	0
Total depth to bed-rock	263	6

At Castlemaine and Bendigo, where extensive denudation has taken place, deposits which are the analogues of the deep leads of Ballarat stand out on the surface in the form of bosses. These have frequently been cut through by recent streams, and in such cases the drift in their beds consists partially of the *debris* of these older deposits, and in part of fragments of adjoining quartz-bearing strata. In fact, drifts of three or four different ages may sometimes be observed in the bed of the same stream.

It would be impossible to enumerate the results obtained by any large number of undertakings worked upon deep leads, but in order to convey some idea of their former richness in the vicinity

[1] "Geological Survey of California," p. 250.

of Ballarat the following examples may be cited. At Gum-Tree Flat a party of six men took out 1,344 oz. of gold in ten weeks, and at the same place another party obtained gold to the value of £24,000 in four months. A third party, of eight men, got £20,000 in five months. According to Mr. Wood, who furnished Mr. R. Brough Smyth with a comprehensive statement relative to the operations of some of the more important mining companies then working at Ballarat, forty-two of them had, previous to the year 1869, yielded gold of the aggregate value of £4,305,563.

Mr. Brough Smyth states that he had taken considerable pains to collect authentic information with regard to drifts believed to be of Miocene age, and not supposed to contain gold in sufficient quantities to repay the miner for its extraction. Among other facts bearing upon this subject, attention is called to the circumstance that in sinking the prospecting shaft of the Golden Rivers Company, after passing through a drift containing well-rounded quartz pebbles associated with large quantities of iron pyrites, the miners struck a seam of black clay enclosing fossil trees with a little fine gold, and beneath this was a thick stratum of sandy clay with small fragments of fossil wood. On the bed-rock, composed of a hard yellow sandstone, gold was obtained from every sample washed; and further exploration showed that gold was present wherever the sandstone was laid bare, although not in sufficient quantity to pay for working. The flow of the ancient channel appears to be north-east, and the drift therein deposited is probably of Miocene age.

Mr. Selwyn gives the following section of the strata near Golden Rivers.[1]

1. Upper basalt, twenty-five to thirty feet.
2. Pliocene gravel, about fifty to sixty feet.
3. Miocene gravel, &c ("false bottom" of miners) gravel, sand, clay, and boulders, with fossil leaves and wood, about 400 feet.
4. Silurian slates, &c.

In a claim at Wombat Hill, Daylesford, a pipe or dyke of basalt was met with which caused the miners considerable trouble and expense. Believing it to form a portion of a basaltic capping of the ordinary character, they sunk a winze upon it from the floor of their tunnel to a depth of 170 feet without finding any bottom, but subsequently they drove through it and discovered the gutter on the other side. This dyke (Fig. 81), after R. Brough Smyth, is about fifty feet in width, and the thickness of the overlying capping of basalt 225 feet. It would appear that the drift

[1] "Notes on the Physical Geography, Geology, and Mineralogy of Victoria."

and neighbouring stratified rocks were but very slightly, if at all, disturbed by the passage of the dyke through them, which, under the circumstances, is somewhat remarkable. The shaft shown in the section was sunk to a depth of 130 feet, and the strata passed through consisted of surface soil, 10 feet; basalt, 80 feet; and Silurian schist, 40 feet. The miners then drove 390 feet east, and there encountered the basaltic dyke, which courses in a south-easterly direction. They afterwards sank 170 feet, following the western limit of the basalt; but, finding it continuous, extended the original south-easterly level, and found the lead on the other side, which abruptly terminated at the edge of the dyke.

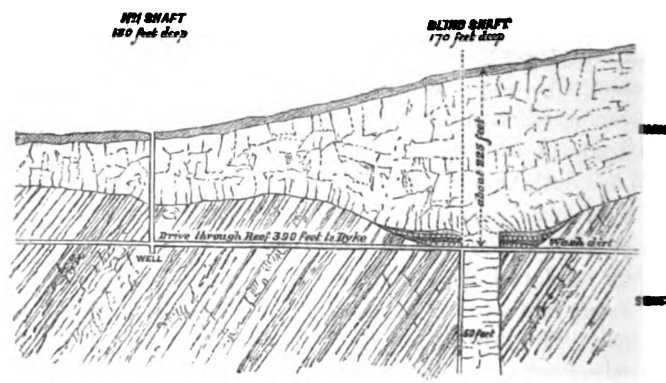

FIG. 81.—Section at Wombat Hill, Daylesford.

In all the gold-fields of Victoria a stratum of ferruginous conglomerate, composed of rounded pebbles of quartz, angular fragments of the same rock, and small pieces of schist, is occasionally found overlying the bed-rock. This it in some places touches, while in other places it may be situated from a few inches to several feet above it. At Sandhurst, Maryborough, Castlemaine, in some parts of the Beechworth district, and at Ararat, the cement has been highly auriferous; but its hardness prevents the ready separation of its gold by the ordinary process of sluicing and washing. In fact, in some places it is so hard that blasting has to be resorted to. At Ballarat the cement, which varies from two to eight feet in thickness, occurs as a dark brown mass, consisting of a mixture of pebbles and quartz boulders, united by a cement strongly coloured by hydrated ferric oxide. The hardness of auriferous cement often renders it necessary that it should be sent to the stamping mill, where it is treated like ordinary gold quartz. At Sandhurst cement occurs in the shallow alluvium as well as in the deep leads, and was in some places very rich. The gold embedded in it is in the form of grains, scales, and small nuggets. In some places these conglomerates have averaged as much as 12 oz. of gold to the ton. As might be anticipated, the distribution of the gold is exceedingly irregular, and at one place in the Ararat district a parcel of 20 tons of cement yielded nearly 360 oz. Some of these conglomerates, as well as the ordinary auriferous drifts of Victoria, contain pebbles and imperfectly rounded grains of cassiterite.

Among the unusually large nuggets which have at various times been found in this colony, the most valuable was the "Welcome Stranger," found near Dunolly, which weighed 2,280 oz. and afforded 2,268 oz. of gold. The next largest, the "Welcome Nugget," was found at Ballarat, at a depth of 180 feet, in June 1858; it was much water-worn, had attached to it about 10 lbs. of quartz, clay and oxide of iron, and contained 2,166 oz. of gold. The "Blanche Barkly," was found in Kingower, at a depth of 13 feet, and had attached to it about 2 lbs. of quartz, oxide of iron, &c. This nugget yielded 1,743 oz. 13 dwt. of gold, of the value of £6,905 12*s.* 9*d.* In 1851 a nugget was found by a native among a heap of quartz on the surface of the ground at Meroo Creek on the Turon river. When discovered it was in three pieces, which together weighed about 1¾ cwt., and consisted of 1,272 oz. of gold with nearly 1 cwt. of quartz. Numerous other nuggets yielding each above 1,000 oz. of gold, besides almost innumerable smaller ones, have at different periods been found in Victoria, and have been met with at all depths, from the surface of the ground to the top of the deepest bed-rock.

Numerous theories have, at different times, been propounded to account for the origin of nuggets. By one of them it is suggested that they may have grown in the sands and gravels in which they are found, and may even yet be gradually getting larger through the addition of successive layers of gold. Evidence of the presence of gold in the deep leads in a state of solution, and of its subsequent deposition in the metallic state within comparatively recent times, is supposed to be afforded by the auriferous character of some of the pyrites found in the ancient drifts at Ballarat and elsewhere, which, although still retaining the form of roots and branches, contains gold. Mr. H. A. Thompson states that a fine specimen of crystallized iron pyrites, deposited on a piece of wood taken from the drift immediately below the basalt at Ballarat, gave by assay

40 oz. of gold per ton ; and in another case, in which iron pyrites from the centre of an old tree-trunk was assayed, the yield was at the rate of above 1 oz. 10 dwt. of gold per ton.

An accidental discovery made some years ago by Mr. Daintree, and some more recent experiments by Mr. Wilkinson, are also supposed to be favourable to this hypothesis. Mr. Daintree's discovery consisted in the fact that if a speck of gold be placed in a solution of the chloride of that metal, and a fragment of wood or cork be also introduced, a deposit of gold takes place, and the original fragment gradually increases in size. Mr. Wilkinson's experiments further prove that under similar circumstances iron pyrites, chalcopyrite, mispickel, galena, and various other minerals serve as a nucleus on which a deposit of gold may take place. From this it is argued that the organic matter, so abundant in the drift, may be the agent by which gold has been precipitated from solution. Although this very ingenious theory is worthy of consideration, there would appear to be various points relative to which further information would be desirable, and some of the conclusions would seem to be contrary to observed facts.

Large pieces of gold have been found in quartz veins, and very few large nuggets have been discovered which have not been accompanied by a considerable amount of adhering quartz. That masses of gold of considerable weight have been more frequently met with in drifts than in quartz veins, would be readily accounted for by the fact that the former represent a vastly greater mass of original auriferous quartz than has hitherto been removed by the miner directly from the reefs. In the Garibaldi lands at St. Arnaud a mass of gold weighing 500 oz. was found in a quartz vein, and with it various smaller pieces weighing in the aggregate nearly 400 oz.

The fact that alluvial gold is generally purer than that directly obtained from quartz reefs, has also been used as an argument in favour of their having had a different origin. It is, however, well known that stream tin produces metal of a superior quality to that obtained directly from the mine, and in the same way gold which has been long exposed to the action of water and oxidizing influences, will gradually become freed from associated impurities with which it was not combined. Although the purity of alluvial gold is generally superior to that obtained from quartz veins, this is not always the case, and it must be admitted that in the ordinary processes for treating gold quartz, certain impurities with which the metal comes in contact may become alloyed with it and thereby reduce its purity.

A large proportion of the nuggets found occur in the form of pebbles, consisting of a mixture of quartz and gold, presenting a continuous even surface. If, however, in such pebbles, the weight of gold had been augmented by the deposition of successive concentric layers of that metal, a distinct irregularity of the surface might be anticipated, since a growth of quartz exactly equal to that of the gold could scarcely be expected to take place.

If the gold of placers had been deposited *in situ* from solutions, a considerable portion of it would have been crystallized and have formed strings and sheets in the porous material with which it is associated; crystals with entirely unworn edges are, however, never found among placer gold, and strings and sheets of that metal are equally absent.

With regard to uniformity of composition in different parts of the same nugget, Mr. Foord states that he has repeatedly taken samples of different parts of large nuggets with a view of ascertaining the uniformity of their composition or otherwise. Although working with very great care, he had never been able to find a difference in fineness greater than that attributable to working error, say one or two parts in 10,000. Had, however, the results of such experiments differed completely from those obtained, it would not have materially affected the question at issue; since the deposition of gold in veins probably took place by the addition of successive layers; and it will be readily understood that the purity of each may not in all cases have been exactly the same.

It not unfrequently happens that the quartzose veinstone forming part of a nugget exhibits peculiar characteristics, strikingly resembling those of some well-known quartz reef in the approximate vicinity of the locality in which it was found, and from which it would appear to have been originally derived.

On the whole, the balance of probability is perhaps, at present, in favour of the theory which ascribes the origin of gold nuggets to the action of mechanical forces upon the outcrops of veins of auriferous quartz. With regard to deep leads generally, it is manifest that in the majority of cases they owe their preservation to the protective influence of a capping of volcanic rock.

Wherever within the gold-regions of Victoria the Palæozoic bed-rock has been exposed, either by natural denudation by the removal of Tertiary drifts, or by mining beneath the basalt, it is found to enclose auriferous reefs. These, which vary in width from the thickness of a sheet of paper to 150 feet, traverse mudstones and sandstones containing various Palæozoic fossils.

The quartz constituting some of these veins is milk-white in colour, nearly amorphous in structure, and breaks with a somewhat splintery fracture. In other cases the veinstone is more or less stained by ferric hydrate, resulting from the decomposition of iron pyrites. On the other hand, many veins consist of comby or banded quartz, enclosing parallel splintery fragments of the slaty country rock, and containing crystals of pyrites, blende, and other metallic sulphides. The quartz of the more productive veins is either granular or crystalline, and a thin film of gold sometimes occurs between the faces of adjacent crystals. Gold occurs not only in the veinstone of such veins, but also in their casings or selvages, where it assumes the form either of irregular fragments or of more or less perfect crystals.

On sinking upon an auriferous reef a point is reached at a certain depth from the surface where water begins to be troublesome, and at which it constantly maintains its level; among miners this is known as the "water line." Above this horizon the quartz, which is usually granular, is often stained by ferric hydrates resulting from the oxidation of iron pyrites; it will also usually contain cavities having a cubical form produced by the decomposition and removal of crystals of pyrites.

These hollows often contain free gold, liberated by the oxidation of the metallic sulphide, which is frequently associated with ochreous iron oxide resulting from the same cause. Cavities of this class have, however, sometimes become partially obliterated by a subsequent growth of quartz in the form of small crystals. Below the water line the metallic sulphides are undecomposed, and often enclose a large proportion of the gold present in the vein. If a fragment of this rock containing gold thus enclosed in undecomposed pyrites, be attacked by nitric acid, the metallic sulphide is dissolved and the gold becomes liberated. Above the water line of the district a nearly analogous change has taken place, through the oxidation of the sulphides and the removal in solution of the resulting metallic sulphates.

There are, however, certain reefs which, although almost entirely composed of metallic sulphides and cropping out at the surface, appear to have undergone but a small amount of decomposition. The stability of iron pyrites and of its various associated sulphides under circumstances in which, if occurring in ordinary quartz veins, they would have been almost entirely decomposed, is somewhat difficult to explain; it must, however, be remembered that in such cases the proportion of sulphides is so large that an amount of decomposition equal to that which takes place in an ordinary quartz vein would scarcely be observable.

The quartz reefs of Victoria sometimes run parallel to the planes of bedding of the country rock, and then belong to the class of segregated veins, while at others their course is directed across them, thus becoming true lodes. In some instances the same vein may, during certain portions of its course, follow the direction and dip of the enclosing strata, while at others it may cross the bedding nearly at right angles.

An example of a vein of this kind, of which Fig. 82 represents a horizontal section, occurred at Whroo. This vein followed the planes of bedding for short distances, and afterwards repeatedly struck across them at a considerable angle. Both in this vein

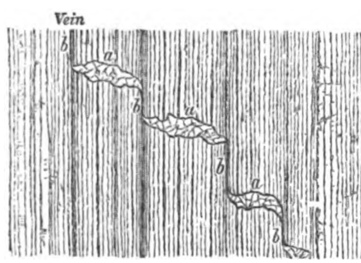

FIG. 82.—Quartz Vein, Whroo.

and in a somewhat similar one in the Caledonia Diggings, the portions marked *a* which cross the strata were not only wider, but also more productive than those marked *b* parallel to the bedding.

In connection with auriferous leads the presence of gold in slate is by no means an uncommon occurrence. A remarkable deposit of auriferous slate was met with a few years since at Clunes, where, for a short distance, the vein fissure had not become filled with quartz. The space between the two walls was however occupied by rich auriferous slate, the surfaces of which were covered by a thin film of gold. In many cases, true veins crossing the planes of the enclosing country rock throw off, parallel to the stratification, branches which are sometimes rich in gold.

Remarkable formations of gold-bearing quartz, occurring in the form of nearly horizontal deposits, are worked in some localities in Victoria. At the Morning Star, Wood's Point, a dyke of "decomposed granite" underlies to the west, and is traversed by a series of more or less horizontal quartz veins situated one below the other, and having no connection. Portions of the dyke are frequently found enclosed within these veins in the form of horses.

Another remarkable example of the occurrence of quartz in horizontal flats is seen at the Waverley Mine in the same neighbourhood, of which Fig. 83 represents a transverse section. The quartz is here enclosed in a nearly vertical dyke of partially decomposed "greenstone," which runs with the strike of the slate for a distance of a mile and a half. It has two well-defined and nearly parallel slate walls, about three feet six inches apart; and the rock constituting

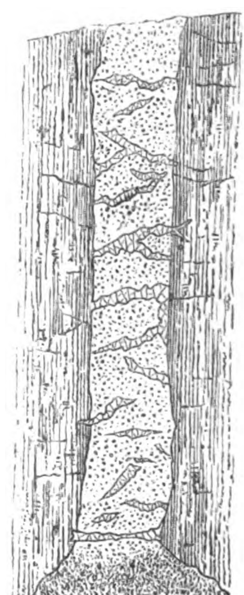

FIG. 83.—Dyke, Waverley; transverse section.

the dyke, besides being much decomposed, is traversed horizontally by bands of quartz varying in thickness from one inch to two feet. Some of these bands have yielded quartz equal in richness to any ever found in the district, and the general average of the whole has been a good one. A feature peculiar to all reefs of this description is that, at depths varying from 70 to 200 feet, an undecomposed crystalline rock is met with, which is so hard as to prevent all further sinking. Gold is found in small quartz veins which run through this undecomposed rock in the same way as they occur in the decomposed portions at shallower depths. The *mullock*, or decomposed greenstone, of the Waverley dyke is said to yield small rubies, and is itself to some extent auriferous. The gold from this locality is described as being more than usually pure.

Instead of occurring in dykes of eruptive rock, somewhat similar bands of auriferous quartz have been known to traverse, in almost the same manner, certain bands of slate tilted at a high angle. An example of this class of formation occurs in the Bendigo gold-field, where a seam of graphitic clay, standing at a high angle, follows the direction of the usual bedding of the slate, while, at a distance varying from thirty to forty feet west of it, there is a band of hard sandstone closely resembling quartzite. The space between this band of clay and the sandstone is occupied by a dark slate, similarly bedded, across which lie numerous nearly horizontal beds or floors of quartz. These frequently penetrate for a short distance into the sandstone, but none of them pass into the clay forming the eastern wall. Together, these seams form a band nearly 200 feet in depth, which in some places crops out on the surface, and dips gradually towards the north. Some of the quartz veins forming the upper members of this band were exceedingly rich, those near the surface affording above 20 oz. of gold per ton; the yield, however, gradually decreased in depth, while, at the lowest point reached, the slate had become changed into a hard compact rock, and the quartz was comparatively unproductive.

Mr. Thompson describes reefs of auriferous quartz which he calls "pipe veins"; the Achilles Reef at Taradale being cited as a vein belonging to this class. This reef, which at its outcrop is from 20 to 25 feet wide, is 45 feet in length, and has been traced for a considerable distance from the surface without having undergone any material variation in size. This "pipe," which is described as being in connection with a thin, nearly vertical band of quartz sometimes carrying gold, underlies rapidly towards the south, and, although the rock beneath it was sunk through for a considerable distance, no other formation of a similar character was met with. At the surface this vein was exceedingly rich throughout its whole width, but as the mine became deeper the gold gradually fell off in quantity, until at length only a few feet on each side were worked, the quartz in the middle being too poor to pay the cost of extraction. The richest quartz was obtained from the foot wall of the deposit. To the east of the vein is a hard crystalline slate, while to the west of it the rock is much softer, and there is no indication of the presence of any other "pipe" of quartz either to the north or south of its outcrop. The string of quartz which occurs in connection with this "pipe" is described as being little more than a joint, with branches of quartz falling into it at intervals, and following the direction and dip of the strata.

The veins of the Victorian gold-fields are represented as frequently exhibiting a tendency to dip in the direction of their bearing, and instances of this peculiarity are stated to occur in every gold-field of the colony. One of the most marked cases of this mode of occurrence is that of the Mariner's Reef at Maryborough, which crops out at the surface in a low range, and, within 1,000 feet of horizontal distance, dips some 650 feet vertically. It is not improbable that further explorations may lead to the

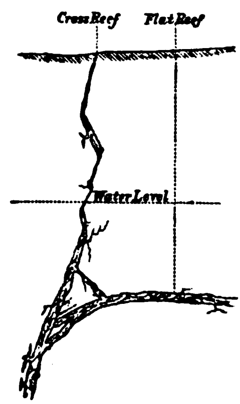

FIG. 84.—Cross and Flat Reefs, Pleasant Creek.

conclusion that some of these so-called "pipe veins" are merely sudden local enlargements of ordinary quartz veins, which, like courses of ore in all mining districts, have a tendency to dip in the direction of the course of the vein. Others may be found to be portions of quartz reefs displaced by two nearly parallel faults; and of which the dip has been mistaken for the strike. Some of the reefs at Pleasant Creek, in the Ararat district, present very unusual features. Many of these have been remarkable, not only for their good average yield of gold, but also for their horizontal bed-like mode of occurrence, their extraordinary faults, their peculiar contortions, and their detached and broken masses. Fig. 84 represents a transverse section of portions of the Cross Reef and Flat Reef, which are worked in that locality. The veinstone of the Cross

Reef is said to be generally laminated, with a casing upon the hanging wall varying from 6 to 8 inches in thickness. Those portions of the vein in which the quartz does not occur in the form of successive laminæ usually contain but little gold. Mispickel and iron pyrites are abundant in some parts of the reef, and frequently occur in the form of crystalline masses accompanied by gold. This was especially the case at the junction of the two reefs, where the richest specimens of auriferous quartz were obtained, at a depth somewhat above the original water level of the district. The Flat Reef is composed of compact white quartz, without any sort of casing, through which the gold, which is usually coarse, is very unequally distributed. It would appear, however, to be chiefly confined to certain imperfectly defined bands passing through the reef in a northerly direction. In some of these auriferous zones the quartz averaged 7 oz. of gold per ton, but outside of them the yield was usually not more than 3 or 4 dwt. per ton. Both the Cross and Flat Reefs varied considerably in thickness; the former from 3 inches to 24 feet, and the latter from 2 to 8 feet.

A section of the Flat Reef, given by Mr. R. Brough Smyth, shows it to extend for a considerable distance, and to connect the Cross Reef with the Mariner's Reef; no scale is, however, given, and as the description is somewhat general in its character it becomes difficult to clearly understand the exact mode of occurrence of these reefs. Such deposits may probably, in some respects, resemble the metalliferous flats which in many mining districts are associated with mineral veins, or, as has been suggested, their position may sometimes be due to a folding of the strata subsequently to their formation.

The early miners, both in Australia and in California, were generally impressed with the idea that the outcrops of the quartz reefs were more productive than their deeper portions, and this opinion was, to some extent, strengthened by a theory to the same effect promulgated by Sir R. Murchison. Consequently, as soon as the quartz extracted ceased to afford remunerative returns, the miners not unfrequently suspended their operations without extending them to any considerable depth. The experience of the gold-fields of Australia, like those of California and other gold-producing countries, however, shows that there is apparently no fear that the reefs will cease to be productive at any depth to which the miners are likely to follow them.

It is, however, by no means remarkable that the opinion should have got abroad that quartz veins usually become impoverished in depth. Metalliferous veins are exceedingly variable in their yield at different depths, and it will, therefore, be readily understood that those were first operated on which, at the surface, showed evidence of being more or less auriferous. Such veins, after having been followed to a certain depth, may, therefore, be naturally expected to begin to exhibit signs of poverty, and, although sinking deeper might lead to fresh discoveries, the miners in a country in which capital is scarce and wages high, will finally transfer their operations to other outcrops showing a remunerative amount of free gold.

Another cause of the misconception with regard to the poverty of auriferous veins in depth, arises from the fact that, in many cases, the gold is chiefly confined to shoots of auriferous quartz. These, like courses of lead or copper ores, dip in the direction of the course of the vein, while in other portions of the lode the veinstone is comparatively destitute of gold. Where, therefore, one of these inclined longitudinal courses of auriferous quartz had been worked through and the shaft sunk to a greater depth, the yield naturally fell off, and the mine was often abandoned. Sometimes, however, in consequence of the success of adjoining mines, or from some other cause, the workings were subsequently continued in depth, and another shoot of rich quartz was found. In this way a knowledge of the mode of occurrence of such deposits has been gradually acquired, and at the present time this tendency of auriferous quartz to form diagonal shoots has become fully recognised both in Australia and California, where some of the deepest mines produce, from their lowest levels. quartz as rich in gold as any obtained nearer the surface. The principal quartz veins of Victoria occur in rocks of Lower Silurian age, but are not exclusively confined to that formation. They were generally formed previous to the deposit of the Mesozoic strata, which rest unconformably upon the upturned edges of Palæozoic rocks, which are everywhere penetrated by veins which do not extend upwards into Mesozoic strata. There can also be little doubt that, in at least the majority of cases, the gold was deposited contemporaneously with the quartz, of which the veins chiefly consist. The granites of the colony sometimes contain gold in the vicinity of their junction with the older sedimentary rocks. The direction and dip of the quartz reefs of Victoria are so extremely variable as to admit of no general description.

Some specimens of quartz taken from a vein near Maryborough exhibited features of considerable interest, as they appear to indicate that at least some of the quartz veins of this colony were formed slowly and at low temperatures. Thin fragments of the enclosing slaty rock were found adhering to, and enclosed in, the quartz of this vein, which everywhere presented an exact cast of all the irregularities of the adjacent schist. This schist contained numerous cubical crystals of iron pyrites, and wherever a portion of one of these crystals was partially exposed, either on the surface of the enclosed fragments or on that of the country rock, a perfect cast of it was found in the adjoining quartz.

In a paper read before the Geological Society of London in April 1872,[1] Mr. Richard Daintree drew attention to the fact that the auriferous Devonian districts of Queensland are entirely confined to such as are penetrated by certain eruptive rocks; principally pyritous diorites. In these diorites, and near the point of their intersection with the Devonian strata, veins of quartz, calc-spar, and iron pyrites, had been examined and found rich in gold, while the extensions of such veins at any considerable distance from the intrusive rocks were found to be barren. Instances were also adduced to show that the pyrites sporadically distributed through the diorites was occasionally distinctly auriferous, and had, by its decomposition and disintegration, produced drifts containing gold in paying quantities.

In a subsequent communication,[2] Mr. Daintree states that since the date of his first paper he had learned from Mr. C. Wilkinson, the Government Geologist of New South Wales, that the same facts hold good for the New South Wales gold-fields lying in Upper Silurian or Devonian areas; and Mr. G. H. F. Ulrich, the Curator of the Technological Museum in Melbourne, in his catalogue of the rocks in that institution, gives details which go to show that the Upper Silurian rocks of Victoria owe their auriferous character to the same cause.

He describes the diorites of Victoria as occurring mostly as dykes, varying in thickness from a few feet to several hundred, traversing Upper Silurian strata and presenting nearly all the ordinary varieties of structure and composition of that rock. They are nearly always impregnated with auriferous pyrites, and are either

[1] "Notes on the Geology of the Colony of Queensland," *Quart. Jour. Geol. Soc.*, vol. xxviii. 1872, p. 271.

[2] "Note on Certain Modes of Occurrence of Gold in Australia," *Quart. Jour. Geol. Soc.*, vol. xxxiv. 1878, p. 431.

traversed by or associated with quartz veins. According to Mr. Ulrich, by far the greater proportion of the quartz gold furnished by the gold-fields occupied by Upper Silurian rocks, is derived from dykes of diorite. In support of these statements he mentions several important workings in connection with dykes of this kind, and especially notices that of Cohen's Reef, which is perhaps the richest in the colony, and the dyke of the Albion Mining Company at Crossover Creek, in North Gippsland, which is interesting on account of its highly micaceous character and its influence on the gold-bearing character of the associated quartz reefs. These, which traverse it nearly at right angles to its strike, are poor in the Upper Silurian rocks on each side, but become richly auriferous throughout the width of the dyke itself, of which the thickness is about ninety feet.

The question as to when the auriferous pyrites was deposited in these diorites is of much interest and one that it will be somewhat difficult to solve. It is, however, probable that in the majority of cases the pyrites was contemporaneous with the consolidation of the rock in which it occurs, although it is also possible that it may have occasionally owed its origin to the subsequent passage through the rock of metalliferous solutions. A large number of sections of pyritous diorites, felsites, and granites, were examined under the microscope by Mr. Daintree, who, in a few instances only, found portions of the enclosing rock embedded in crystals of pyrites.

Below the water level, which usually very nearly coincides with the zone of decomposition, veins of a class which on the whole has proved very misleading to the miner, although often rich in gold, usually disappear. These follow the lines of jointing of the rock, and are probably due to the decomposition of auriferous pyrites in the eruptive rock and the re-deposition, from solution, of a portion of its material in local fissures. It is probable that to this mode of formation are to be attributed the horizontal veins described as occurring at Waverley and elsewhere. Besides the veins above referred to, there are, associated with the intrusive auriferous rocks, others which Mr. Daintree considers as being of far greater practical importance from being generally of greater width and more likely to be persistent in depth. These he regards as the result of hydrothermal agencies which preceded and accompanied the protrusion, and which in some cases continued long after the intrusive rock had cooled down.

The production of gold in Victoria from its discovery in 1850 to 1882 has been as follows:—

TABLE SHOWING WEIGHT AND VALUE OF GOLD PRODUCED IN VICTORIA FROM 1851 TO 1882 INCLUSIVE.[1]

Year.	Alluvial.	Quartz.	Together.	Value at 80s. per oz.
	oz.	oz.	oz.	£
1851 {Three Months			145,146	580,584
1852			2,218,782	8,875,128
1853			2,676,345	10,705,380
1854			2,150,730	8,602,920
1855			2,751,535	11,006,140
1856			2,985,991	11,943,964
1857			2,762,460	11,049,840
1858			2,528,478	10,113,912
1859			2,280,950	9,123,800
1860			2,156,660	8,626,640
1861			1,967,420	7,869,680
1862			1,658,207	6,632,828
1863			1,626,872	6,507,488
1864			1,544,694	6,178,776
1865			1,543,801	6,175,204
1866			1,479,194	5,916,776
1867			1,433,687	5,734,748
1868	1,087,502	597,416	1,684,918	6,739,672
1869	934,082	610,674	1,544,756	6,179,024
1870	718,729	585,575	1,304,304	5,217,216
1871	698,190	670,752	1,368,942	5,475,768
1872	639,551	691,826	1,331,377	5,325,508
1873	504,250	666,147	1,170,397	4,681,588
1874	433,283	664,360	1,097,643	4,390,572
1875	426,611	641,806	1,068,417	4,273,668
1876	357,901	605,859	963,760	3,855,040
1877	289,754	519,899	809,653	3,238,612
1878	264,453	493,587	758,040	3,032,160
1879	293,310	465,637	758,947	3,035,788
1880	299,926	529,195	829,121	3,316,484
1881	—	—	858,850	3,435,400
1882	352,078	512,532	864,610	3,458,440
Totals . .	—	—	50,324,687	201,298,748

According to the mineral statistics of Victoria for the year 1880, the approximate area of auriferous ground over which mining operations had extended up to the end of that year was 1,235¼ square miles, and the number of distinct reefs proved to be auriferous 3,630. The deepest shaft in the colony, at

[1] The figures given previous to 1868 are the amounts and values of the gold exported only, and are consequently under the truth. Those for 1868, and for subsequent years, represent the actual production as calculated by the Mining Surveyors and Registrars.

Stawell, was 2,410 feet deep; at Sandhurst there was a shaft 1,476 feet deep, at Maldon one of 1,220 feet from the surface, and at Clunes two shafts were respectively 1,193 and 1,105 feet deep. The average fineness of the gold of Victoria is nearly 942.

During the year 1880, 31,456 tons of quartz obtained from the Ballarat mining district, at depths varying from 200 to 1,105 feet from the surface, yielded from 6 dwt. 1 gr. to 14 dwt. 11 gr. of gold per ton; 2,770 tons of quartz, taken from depths varying from 200 to 600 feet, from the Beechworth district, yielded from 8 dwt. to 4 oz. 16 dwt. 7 gr. of gold per ton; 17,216 tons of quartz obtained at Sandhurst, at depths varying from 400 to 1,267 feet, yielded from 13 dwt. 11 gr. to 2 oz. 9 dwt. 22 gr. of gold per ton; 15,112 tons of quartz from the Maryborough district, obtained at depths varying from 305 to 680 feet, yielded from 12 dwt. 6 gr. to 6 oz. 13 dwt. 3 gr. of gold per ton. In the Castlemaine mining district, 6,202 tons of quartz obtained at depths varying from 200 to 500 feet, yielded from 18 dwt. to 3 oz. 17 dwt. 3 gr. of gold per ton; 6,281 tons of quartz obtained at Stawell, at depths varying from 612 to 1,200 feet, yielded from 1 oz. 6 dwt. to 4 oz. 12 dwt. 16 gr. of gold per ton. At Stringer's Creek, in the Gippsland mining district, 19,621 tons of quartz, obtained at depths varying from 343 to 723 feet below adit, yielded from 1 oz. 4 dwt. 22 gr. to 1 oz. 6 dwt. 22 gr. of gold per ton.

SILVER.—Argentiferous galena and embolite are found at St. Arnaud, associated with iron pyrites, mispickel, chalcopyrite, malachite, native copper, native silver, gold, cerussite, anglesite, mimetesite, blende, native sulphur, brown iron ore, and oxide of manganese. Some of the stibnite of Victoria has been found to contain silver in the proportion of 80 oz. per ton. Embolite is found at St. Arnaud in cavities in drusy quartz above the water level, and is probably a secondary product resulting from the decomposition of argentiferous galena. Silver ores likewise occur at Ararat, Pleasant Creek, Morse's Creek, Sandhurst, Heathcote, Reedy Creek, and elsewhere.

During the year 1880 no silver ores were raised, but 169 oz. 15 dwt. of that metal were parted from gold in the St. Arnaud district, and 23,078 oz. 15 dwt. were parted from gold melted at the Melbourne mint. The total yield for the year was, therefore, 23,248 oz. 10 dwt.

LEAD.—Galena occurs in many of the reefs at Sandhurst; near Blue Mountain, with malachite and yellow copper ore; in Gippsland; in Campbell's Reef at Moyston; at St. Arnaud; and in various other localities. Although it is of common occurrence, this mineral has not been anywhere obtained in large quantities. Below the water level of St. Arnaud it is, however, sometimes met with in the form of strings and patches. It is always argentiferous, and at St. Arnaud contains above 100 oz. of silver per ton. No lead ore was raised in Victoria during the year 1880.

COPPER.—Native copper is found in some of the St. Arnaud veins, and the green and blue carbonates of that metal occur, above water level, in many of the reefs throughout the colony. Copper pyrites is found in diorite on the Thompson River, about five miles south of the junction of that stream with Stringer's Creek. The vein is said to be sometimes as much as 35 feet in width. Mining operations were in progress in this place as early as 1868, and smelting furnaces had been erected on the opposite bank of the river. According to official returns, 3,030 tons 10 cwts. of copper ore were raised in the colony during the year 1880, and 3,938 tons were smelted; 262 tons of copper and 17 tons 11 cwts. of regulus were exported.

TIN.—The alluvial tin ore obtained during the year 1880 amounted to 103 tons 10 cwts. Stream tin is found in the Beechworth district, in the tributaries of the Lerderderg, at Gympie near Steiglitz, in the tributaries of the River Yarra, in the basin of the River Thompson, and in many of the feeders of the Latrobe River, &c. During the year 1882, 1,077 tons of tin ore were produced.

ANTIMONY.—Stibnite, with valentinite and other oxidized ores of antimony, occurs in various places in the colony. At Whroo very remarkable concretions are found in the veins. They assume the form of concentric layers of differently coloured oxides surrounding a central nucleus of sulphide of antimony. All through the oxidized portions gold is disseminated in the form of ragged grains varying in size from a mere speck to pieces as large as a pea. A vein containing sulphide of antimony was discovered some years ago at Munster Gully, Dunolly; and at Donovan's Creek, on the Upper Yarra, a lode, varying from one foot six inches to two feet in width, consists almost entirely of bright and nearly pure stibnite. At Sunbury there is a vein consisting chiefly of quartz and sulphide of antimony; this has an irregular course chiefly along the strike of the Silurian strata, but in some places crossing them obliquely. In addition to antimony, this lode, which varies in thickness from 3 to 18 inches, contains about 2 oz. of gold per ton. Another vein of auriferous antimonial ore is said to occur only seventeen miles from Melbourne. The antimony mines of Costerfield were discovered many years ago, and have been since wrought with varying success. During the year 1880 there were raised 333 tons 17 cwts. of antimony ore, of which 272 tons 17 cwts. were smelted in the colony, and from which 178 tons 10 cwts. of regulus were obtained; 85 tons of antimony ore and 323 tons of regulus were exported. During the year 1882, 375 tons of antimony ore were raised.

NEW SOUTH WALES.

In addition to its pastoral and agricultural resources, New South Wales is rich in minerals, yielding, besides coal and oil, shales of exceptionally good quality, gold, silver, copper, tin, and other metals. This is the oldest of the Australian settlements, having been first colonized in the year 1788. Among its principal mining districts are Bathurst, Tambaroora and Turon, Mudgee, Lachlan, Southern Tumut and Adelong, Peel and Uralla, Hunter and Macleary, and New England and Clarence.

GOLD.—Gold occurs in New South Wales, under conditions almost precisely identical with those characterising the auriferous deposits of the adjoining colony of Victoria. It is found in recent alluvium, in leads of Tertiary age, and in quartz veins; in addition to these deposits, the lowest beds of the Coal-measures, which, north of Gulgong, cover a large area of country, are sometimes remuneratively auriferous. The existence of these ancient conglomerates containing gold, appears to indicate that at least some of the auriferous quartz reefs of Australia were formed prior to the Carboniferous period. The Rev. W. B. Clarke speaks of a lump of gold having been found in a mass of coal, and states that much of the gold in New South Wales has been derived from iron pyrites, diffused through granite and various beds of sedimentary origin, consisting of siliceous materials cemented by oxide of iron resulting from the decomposition of pyrites. Daintree, Hacket, Wilkinson, and others have shown that a large portion of the gold in Victoria and Queensland is due to the agency of intrusive dykes of felstone, elvan, and diorite, so that reefs of quartz in Silurian rocks are not, as was at one time supposed, the exclusive source of Australian gold.[1] Many of the deep leads are here, as elsewhere, covered by flows of basalt, and sometimes enclose, not only vegetable remains, but also fossil insects. At Montreal, on the south-eastern side of

[1] "Mines and Mineral Statistics of New South Wales," p. 153, Sydney, 1875.

Dromedary Mountain, a discovery of gold has been made immediately upon the sea coast. This field contains rich deposits of water-worn gold, which has evidently been reduced to its present condition by the action of the sea, by which it has been arranged in two distinct terraces, of which the lowest is somewhat above the present high-water mark.

The quartz reefs of New South Wales, like those of Victoria, often run parallel to the bedding of the enclosing rocks, but they nevertheless sometimes cross it at considerable angles. Occasionally tin oxide is found in the same veinstone. Some of the quartz reefs of New South Wales have, for limited distances, been exceedingly rich. Masses of auriferous material which were nearly all gold, weighing about 100 lbs. each, were blasted in 1872 at a considerable depth from a vein at Hill End. One claim yielded 30,000 oz. of gold from 436 tons of quartz, and another produced 1,567 oz. of gold from 22 tons.[1] Such yields are, however, quite exceptional, as the average produce of the quartz treated in 1880 amounted to only 15 dwt. 17·54 gr. of gold per ton. At the close of the year 1880 the depth of the deepest shaft in the colony was 840 feet. The auriferous area is approximately estimated at 7,000 square miles.

The following table, collected from official sources, shows the annual production of gold in New South Wales from the date of its discovery in 1851 to the end of 1882.

TABLE SHOWING WEIGHT AND VALUE OF GOLD PRODUCED IN NEW SOUTH WALES FROM 1851 TO 1882 INCLUSIVE.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	oz.	£		oz.	£
1851	144,120	468,336	1867	271,886	1,053,578
1852	818,751	2,660,946	1868	255,662	994,655
1853	548,052	1,781,172	1869	251,492	974,148
1854	237,910	773,209	1870	240,858	931,016
1855	171,367	654,594	1871	323,609	1,250,484
1856	184,600	689,174	1872	425,129	1,643,581
1857	175,949	674,477	1873	361,784	1,395,175
1858	286,798	1,104,174	1874	270,823	1,040,329
1859	329,363	1,259,127	1875	230,883	877,694
1860	384,053	1,465,372	1876	167,412	613,190
1861	465,685	1,806,171	1877	124,111	471,418
1862	640,622	2,467,780	1878	119,665	430,033
1863	466,111	1,796,170	1879	109,650	407,219
1864	340,267	1,304,926	1880	118,600	441,543
1865	320,316	1,231,243	1881	149,627	566,513
1866	290,014	1,116,403	1882	140,469	526,512
		Totals		9,365,638	34,870,362

[1] T. Richards, "New South Wales in 1881," p. 63.

Like the other Australian colonies New South Wales sometimes suffers from prolonged droughts, and the supply of water available for mining purposes materially affects the amount of gold obtained during each year. The average fineness of the gold of New South Wales may be taken at about 876.

SILVER.—Comparatively little attention has been directed to silver mining in this part of Australia, and the returns of that metal are by no means as complete as could be desired, since there is no record either of the amount or value of silver produced between the years 1865 and 1869. Discoveries of silver ores have, however, been made within the last few years at Boorook, and there now appears to be some probability that at a future period New South Wales may become a silver-producing country upon an extensive scale.

The Boorook silver mines are situated in a hilly country twenty-six miles north-east of Tenterfield, and are worked upon lodes chiefly enclosed in sedimentary rocks, some of which are highly metamorphosed. The main range of granite is distant from two to three miles from the mines, and porphyries and crystalline schists occur in their immediate neighbourhood. The fossils enclosed in some of the stratified rocks indicate that they are of Upper Devonian age. The veins are numerous and traverse a considerable extent of country, but up to the present time they have only been explored by comparatively shallow workings. Their general strike is east of north and west of south, while their dip is usually towards the south. Samples of the ore have yielded by assay as much as 522 oz. of silver per ton. The appliances available for the reduction and treatment of the ores are represented as being inadequate to the requirements of the district, and the development of the mines has been much retarded in consequence.

Argentite appears to be one of the principal sources of silver, but pyrargyrite and horn silver are likewise present, the associated minerals being iron pyrites, chalcopyrite, galena, blende, and oxide of iron. The veinstone is principally quartz, and always contains a certain amount of gold; the proportion found in the samples assayed varying from 5 gr. to 18 oz. per ton. No constant relation appears to exist between the relative amounts of gold and silver present in different samples. According to Mr. Davey, at depths of less than eighty feet from the surface the silver occurs chiefly in the form of chloride, and is therefore readily obtained by amalgamation; while below that point the ores require a preliminary roasting with salt. Mr. Davey remarks that argentiferous iron pyrites carrying gold would have been most efficiently treated by smelting with lead ores, had the necessary plant and fuel been available.

The most important silver mine of the district is the Golden Age, which is worked in a buff-coloured clay slate situated about two miles from the granite. The lode courses about 22° E. of N., has a dip towards the west, and to a depth of about eighty feet averages about twelve inches in width. From the surface down to this level the most abundant ore was chloride of silver, with some argentiferous pyrites. The whole of the lode to this depth has been stoped away, and all the chlorides have been exhausted. About 52,000 oz. of silver and 250 oz. of gold were obtained from this portion of the lode. There were in 1881 at this mine three shafts, the deepest of which reached 130 feet below the surface. For the last fifty feet the average width of the lode was from eighteen to twenty inches, with a band on either side of rich argentiferous pyrites. This pyrites contains silver in the proportion of from 70 to 150 oz. per ton; but at the bottom of the mine the centre of the lode consists mainly of a slaty breccia, which is by no means rich. A mixture of iron pyrites with blende is often rich in the precious metals; specimens of this kind sometimes yielding as much as 800 oz. of silver and 5 oz. of gold per ton of stuff.

The light-coloured clay slate referred to as forming a portion of the country rock of the Golden Age Mine, does not appear to extend beyond the limits of that property. About fifty yards south of the deepest shaft, situated nearly in the centre of the mine, the lode is intersected and displaced by a flucan containing a few lenticular masses of quartz, which, near the surface, were extremely rich for silver. The country rock west of this cross-course differs materially from that of the Golden Age Mine, consisting as it does of a blue fossiliferous slate, whereas on the eastern side no fossils have as yet been found. Below the depth of eighty feet the rock becomes a blue slate which is compact, and is not known to contain fossils. The lode gradually became richer as it approached the cross-course, and was very productive in its immediate vicinity. During the year 1880, rather more than 30,000 oz. of silver were returned from the Golden Age Mine, and nearly 2,000 more from the Addison Lode, Simmons and Donaldson's claim. Mining in the vicinity of Boorook is, however, regarded as in its infancy.

In addition to the silver obtained from silver and lead ores, native gold is invariably alloyed with that metal, and consequently a very considerable quantity of silver has accompanied the Australian gold through various commercial channels. Although in the aggregate the amount will be somewhat large, the value of this silver is relatively so small that it is not taken into consideration in the estimates of gold produced. The following is the official return of the silver produced in the colony of New South Wales from 1862 to 1882.

TABLE SHOWING WEIGHT AND VALUE OF SILVER ORES AND SILVER PRODUCED IN NEW SOUTH WALES PRIOR TO 1869.

Year.	Quantity.	Value.
		£
1862	266 tons ore,	5,320
1863	28 ,,	1,080
1864	13 ,,	130
1865	736 oz. silver.	184
1866	Nil.	
1867	,,	
1868	,,	
	Total prior to 1869	6,714

TABLE SHOWING WEIGHT AND VALUE OF SILVER PRODUCED IN NEW SOUTH WALES FROM 1869 TO 1882 INCLUSIVE.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	oz.	£		oz.	£
To end of 1868	—	6,714	1876	69,179	15,456
1869	753	199	1877	31,409	6,673
1870	13,868	3,801	1878	60,563	13,291
1871	71,311	18,681	1879	83,164	18,071
1872	49,544	12,663	1880	91,419	21,878
1873	66,998	16,278	1881	57,254	13,026
1874	78,027	18,880	1882	38,618	9,024
1875	52,553	12.794			
Totals				764,660	187,429

COPPER.—Copper ores have for many years formed one of the productions of New South Wales, but for some time copper mining was conducted upon a very limited scale. During the earlier periods of mining activity, the cost of transporting bulky ores from the interior of the colony to the sea coast for shipment placed the copper miner at considerable disadvantage as compared with the gold digger. Washing for gold was, therefore, generally preferred to mining for an ore the value of which could only be realised after a large expenditure of time and money. In order to obviate, as far as possible, this difficulty, copper miners, at a comparatively early date, commenced the erection of furnaces for the production of regulus, and the process was subsequently extended to the manufacture of fine copper.

The first mention of copper ores in the statistics of the colony appears to occur in 1858, in which year 58 tons, of the value of £1,400, are stated to have been raised. The first smelting furnaces appear to have been erected about the year 1863, since which date the production of copper ores and copper has steadily and somewhat rapidly increased. Unfortunately, however, the official records of the colony supply more information with regard to the annual production of copper than with respect to the mode of occurrence of its ores.

The Great Cobar Copper Mine, which at the present time is the most important copper mine of New South Wales, is situated almost in the centre of the vast plain which lies between the Darling, the Bogan, and the Lachlan rivers; the country for many miles around being entirely waterless. The rocks consist of Silurian slates, which within the limits of the property are supposed to be traversed by several lodes. Operations have hitherto been confined to the most western one only, upon which four shafts have been sunk. Barton's Shaft had, in 1880, been sunk to a depth of 54 fathoms, and in that year the inspector of mines reported the lode at the bottom to be 46 feet in width and to consist entirely of solid sulphides. At the bottom of Becker's Shaft, which had been sunk to the same depth as the other, a solid course of ore averaging 26 feet in width extended between the two shafts, a distance of about 100 fathoms. From Becker's Shaft on the north, to Renwick's Shaft on the south, the lode had been worked for a length of about 193 fathoms, and consisted of a mixture of carbonates, oxides, and grey copper ores, with oxide of iron, varying in thickness from three to 100 feet.

The rapid development of this mine is shown by the following statistical statement.[1]

Year.	Ore smelted.	Copper produced.
	Tons.	Tons.
1876	1,458	174
1877	4,880	523
1878	8,389	1,457
1879	12,615	1,891
1880	20,566	2,600
1881	21,552	2,568
1882	11,702	1,805
Totals since the mine started, 1876	81,162	11,018

[1] *Annual Report of the Department of Mines for* 1880, p. 217, Sydney, 1881.

The Nimmagee Copper Mine, about sixty-five miles south of Cobar, is one of the most important of the more recent undertakings. Four shafts had, in 1881, been sunk on the property, the deepest of which had reached a depth of 27 fathoms from the surface. In this shaft the lode was 6 feet in width, and entirely composed of good ore suitable for the furnace. An end, going north, had been driven above 60 fathoms through a lode composed of quartz, gossan, and grey copper ore. Another shaft had been sunk for a depth of 12 fathoms through a lode composed of quartz, gossan, iron pyrites, and yellow copper ore. About 500 tons of 16 per cent. ore was lying on the surface ready for the smelting furnaces.

The New Cobar Copper Mine, which is only about eight miles south of Great Cobar, affords satisfactory indications of the presence of large deposits of copper ore. The approximate area of the copper-bearing region of New South Wales has been estimated at about 6,700 square miles.

The following table shows the quantity and value of copper, copper ore, &c. exported from the colony from 1858 to 1882.

TABLE SHOWING THE QUANTITY AND VALUE OF COPPER, COPPER ORE AND REGULUS, THE PRODUCE OF THE COLONY, EXPORTED FROM NEW SOUTH WALES, FROM 1858 TO 1882 INCLUSIVE.

Year.	Ingots.		Ore and Regulus.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons. cwts.	£	Tons. cwts.	£	Tons. cwts.	£
1858	—	—	58 0	1,400	58 0	1,400
1859	—	578	—	—	—	578
1860	—	—	43 0	1,535	43 0	1,535
1861	—	—	144 0	3,390	144 0	3,390
1862	—	—	213 0	5,742	213 0	5,742
1863	23 0	1,680	114 0	420	137 0	2,100
1864	54 0	5,230	—	—	54 0	5,230
1865	247 0	15,820	22 0	545	269 0	16,365
1866	255 0	18,905	23 0	1,885	278 0	20,790
1867	393 0	30,189	2	5	393 2	30,194
1868	644 0	23,297	172 0	4,000	816 0	27,297
1869	1,980 0	74,605	104 0	2,070	2,084 0	76,675
1870	994 0	65,671	6 0	60	1,000 0	65,731
1871	1,350 0	87,579	94 0	1,297	1,444 0	88,876
1872	1,035 0	92,736	417 0	13,152	1,452 0	105,888
1873	2,795 0	237,412	51 0	1,690	2,846 0	239,102
1874	3,638 0	311,519	522 0	13,621	4,160 0	325,140
1875	3,520 0	297,334	157 0	4,356	3,677 0	301,690
1876	3,106 0	243,142	169 0	6,836	3,275 0	249,978
1877	4,153 0	307,181	360 0	17,045	4,513 0	324,226
1878	4,983 0	337,409	236 0	7,749	5,219 0	345,158
1879	4,106 15	256,437	36 7	915	4,143 2	257,352
1880	5,262 10	359,260	131 18½	4,799	5,394 8½	364,059
1881	5,361 0	350,087	132 16	4,975	5,493 16	355,062
1882	4,865 3	321,887	93 1	2,840	4,958 4	324,727
Totals .	48,765 8	3,437,958	3,299 4½	100,327	52,064 12½	3,538,285

TIN.—The most important tin-fields of New South Wales are those situated near the Queensland boundary, but tin ore also occurs, although in less abundance, in some of the more southern portions of the colony. Attention was first called to the probable occurrence of considerable quantities of this mineral by the Rev. W. B. Clarke, to whose investigations relative to the geology and mineral resources of Australia, reference has been already made. In a report to the Colonial Secretary, dated May 7th, 1853, Mr. Clarke strongly expressed his opinion with regard to the probable value of the stanniferous deposits of the New England district, but no practical notice was, at the time, taken of his observations. Washing for tin ore was first actively commenced in New South Wales in 1872, and the New England district quickly became famous for its rich deposits of that mineral. Cassiterite was first recognised among the black sands of the Victorian gold-fields in March 1853, but although the occurrence of tin in that colony is comparatively limited, it was not, as in New South Wales, entirely overlooked. Tin ores from Australia were imported into England long previous to 1872, but they appear to have come exclusively from Victoria.

The tin deposits of Australia are not confined to the beds or banks of modern water-courses, but often extend high up their banks, thus indicating that extensive erosion has taken place subsequently to their deposition. Like gold, tin ore is also found in deep leads, which are sometimes covered by flows of basalt, and many of which are regarded as of Miocene age. Granites appear to be the ultimate source of Australian tin ore, and on high ground unworn crystals of cassiterite are occasionally found as a residuary deposit resting on the surface of decomposed granite. The granites are stated to be of Devonian age, and the tin veins which traverse them do not, as in Cornwall, exhibit an approximate uniformity of strike. The area of the New South Wales tin-fields is estimated at about 8,500 square miles, and 2,200 persons are said to be employed in tin mining.

Tin streams began to be profitably worked early in the year 1872; some of the first deposits of ore having been discovered in the neighbourhood of Bendemeer; and almost simultaneously a large extent of land was taken up for tin mining in the neighbourhood of Watson's Creek, twenty miles west of the last-named locality. Then there came information of tin ore having been found near the Queensland border, and streamworks, some of which proved to be very rich, were opened around Stanthorpe.

After the Stanthorpe mines came discoveries in the vicinity of Dundee, and about the same time the deposits of Cope's Creek, near Inverell, were brought to light. Discoveries at Vegetable Creek quickly followed these, where, as well as at Inverell, the workings were carried out upon a large scale and with very profitable results. Some of these original shallow deposits have been long since worked out, but a large number of deep leads, then entirely unknown, are now in active operation. An enormous quantity of tin ore has been taken from the mines in Vegetable Creek, which may be regarded as the centre of the richest discoveries of that mineral in the colony. From 1872 to December 31, 1880, the total yield of tin (black tin ?) from workings in the Vegetable Creek district, is stated to have amounted to 20,988 tons.[1]

The deep lead worked by Wesley Brothers at Vegetable Creek is one of the richest discoveries of tin-bearing drift ever made in the district, even eclipsing the celebrated deposit worked by the Vegetable Creek Tin Mining Company. After sinking through 90 feet of basalt, 60 feet of which was exceedingly hard, together with various layers of pipeclay, their perseverance was rewarded by the discovery of a bed of rich wash-dirt. When they had followed the rock on which they bottomed, which was dipping rapidly, for a depth of about twenty feet, they came upon the wash, consisting of ten feet of fine sandy drift with a fair amount of stream tin. Below this was a layer of coarse gravelly drift, exactly like that seen in the bed of an ordinary river, which was wonderfully rich. In the year 1879 they were unable to reach the bed-rock on account of the large amount of water, but a new shaft was being sunk with a view of reaching the bottom of the deposit. Fig. 85 represents a section of Wesley Brothers' old shaft looking west.

In 1880 the width of the lead had been proved to be 170 feet, and workings had extended upon its direction for a distance of 340 feet. The wash was found to be exceedingly rich, and in many places was black with tin oxide; but, being composed of gravel and very fine sand, the whole of the workings had to be close lathed and double planked. The yield of black tin, which was 286 tons for the year, would have been considerably larger had there not been a scarcity of water during the earlier months.

The great event of the year 1880 appears to have been the striking of remarkably rich wash-dirt at Rose Valley, near Vegetable Creek, where, after sinking through sixty feet of soft

[1] C. Lyne, "The Industries of New South Wales," p. 190.

grey basalt and twenty of variously coloured pipeclays, exceedingly rich tin-bearing wash-dirt, which varied in thickness from 2 to 8½ feet, was found. The width of this lead was proved to be about 100 feet, and drifts were extended for a distance of 300 feet upon its course. From these workings 553½ tons of tin ore were obtained during the course of nine months.

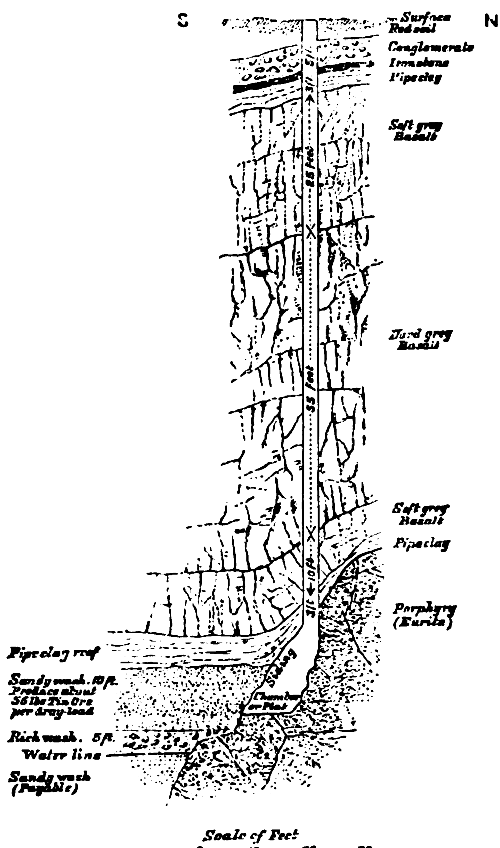

FIG. 85.—Wesley Brothers' old shaft; vertical section.

Although numerous tin lodes are known to exist in various localities in New South Wales, no vein mining of any considerable extent has been hitherto undertaken. Near Cope's Creek in the granitic country, thirty-five miles north-west of Armidale, a number of large stones of solid tin ore were, some years ago, obtained from the outcrop of a lode. One of these lumps is said to have weighed 57 lbs., and to have yielded by assay 76 per cent. of metallic tin. The tin ore at the Bolitho Mine runs in irregular branches through a nearly vertical felspathic dyke. These veins sometimes unite so as to form an almost solid mass of ore, and then again dwindle and disappear. Several large blocks of veinstone raised from this place, one of which weighed nearly a ton, are stated to have mainly consisted of tin ore. At the Bismarck Mine, south of Cope's Creek, a dyke of felstone has been discovered containing tin veins. The tinstone is here associated with quartz in veins varying from a mere string to branches three inches in width, which traverse the dyke in all directions. The ore usually occurs in the form of crystals lining the sides of fissures, the central portions of which are filled with quartz. A vein of nearly pure cassiterite, four inches in width, associated with clay and fluor spar, is said to have be opened at the Boundary Tin Mine.

Several tin lodes occur near Tingha, some of which are stated to have produced solid masses of tin ore several inches in thickness; but with the exception of two, one worked by an Englishman and the other by Chinamen, they were in 1880 all deserted. There are rich tin lodes in the neighbourhood of Vegetable Creek, but rich finds of alluvial tinstone at Rose Valley will tend to check for some time the progress of vein mining in the district.[1]

The following table shows the quantity and value of tin and tin ore exported from the opening of the tin-fields in 1872 to the end of 1882.

TABLE SHOWING THE QUANTITY AND VALUE OF TIN AND TIN ORE, THE PRODUCE OF THE COLONY, EXPORTED FROM NEW SOUTH WALES TO END OF 1882.

Year.	Ingots.		Ore.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£	Tons.	£
1872	47	6,482	849	41,337	896	47,819
1873	911	107,795	3,660	226,641	4,571	334,436
1874	4,101	366,189	2.118	118,133	6,219	484,322
1875	6,058	475,168	2,022	86,143	8,080	561,311
1876	5,449	379,318	1,509	60,320	6,958	439,638
1877	7,230	477,952	124	30,588	7,354	508,540
1878	6,085	362,072	1,125	33,750	7,210	395,822
1879	5,107	343,075	814	29,274	5,921	372,349
1880	5,476	440,615	682	30,722	6,158	471,337
1881	7,590	686,511	609	37,492	8,200	724,003
1882	8.059	800,571	611	32,890	8,670	833,461
Totals .	56,113	4,445,748	14,123	727,290	70,237	5,173,038

[1] *Annual Report of the Department of Mines for* 1880, p. 213.

IRON.—Important deposits of iron ore are found in close proximity to coal and limestone in various parts of the colony. The ore found at Mittagong, in the southern district, contains 65 per cent. of iron. The iron ore at Wallerawang, distant 105 miles from Sydney, consists of magnetite and brown hæmatite, in addition to which there are beds of so-called clay bands interstratified in the Coal-measures. These clay bands are not impure carbonates, but brown hæmatites containing about 50 per cent. of iron. Bands of highly ferruginous garnets accompany the veins of magnetite.

The Eskbank Iron Company, who have established works at Lithgow, 95 miles from Sydney, are the largest manufacturers of iron in the colony. These works are connected by a tramway with the Great Western Railway. The ores treated consist of a clay band stone averaging 40 per cent. of iron, a brown hæmatite yielding 50 per cent. of metal, and a siliceous ore containing a somewhat low percentage of iron. The first, which crops out at the surface, varies from six to fifteen inches in thickness, the second forms a bed two feet thick, while the thickness of the third is four feet. A ten-feet seam of splint coal crops out upon this property, as does also a seam of refractory clay, from which firebricks are manufactured. The make during the year 1880 amounted to 1,200 tons of pig-iron and 800 tons of bars and rails.

LEAD.—At the present time no lead mines are known to be working, but a few tons of lead ore are occasionally exported.

ANTIMONY.—Stibnite occurs in various parts of New South Wales, and during the year 1880 some further discoveries of that mineral were reported to have been made. At a mine opened near Armidale the vein varies in width from 10 to 15 inches, and the ore is stated to yield 50 per cent. of antimony, and 1 oz. 2 dwt. of gold per ton. The ore from another mine is said to yield 66 per cent. of antimony. Antimony lodes have been discovered at Hargraves Falls and in the neighbourhood of Aberfoil. Some lodes in the Macleay district have been worked, while in the Bathurst district, pure blocks of stibnite occur, but without any defined lode. The antimonial ores on the Munga Creek, four miles above its junction with the Macleay River, occur in a quartzose matrix in lodes having a general strike between north and north-east; the Victoria reef is, however, in this respect an exception. Antimony and antimony ores weighing 99 tons 19 cwts., and having a value of £1,652, were exported during the year 1880.

BISMUTH.—This metal occurs in a vein 8 inches wide at Silent Grove, and also in the Vegetable Creek district. It is likewise worked at the Elsmore Mine on the McIntyre River, near Inverell, and in the vicinity of Glen Innes. Although bismuth has long been known to exist in the latter region, mining for this metal, as an industry, was not commenced until 1880, during which year 4½ tons of ore were exported from the Kingsgate Mine, eighteen miles east of Glen Innes. The lodes in which the metal is found vary from 6 to 8 feet in width, and have an east and west bearing. The county rock is granite and the veinstone quartz, from which masses of native bismuth, weighing from 1 to 2 lbs., are sometimes obtained.

QUEENSLAND.

This, the most recently organised of the Australian possessions, was separated from New South Wales in 1859. Its most important metalliferous productions are gold and tinstone, but, in addition to these, Queensland has, in the aggregate, yielded considerable quantities of copper ore.

GOLD.—The gold-fields of the colony, which are grouped in three divisions, namely, the Northern, the Central, and the Southern, exceed twenty in number, but exhibit no peculiarities differing from those which have been already described as occurring in Victoria and New South Wales. Mr. Daintree has called attention to the fact that, although a large area of Devonian rocks exist in Queensland, and numbers of the gold-fields of the colony are situated in Devonian areas, payable gold is under such circumstances only found where the rocks have been penetrated by eruptive dykes which mostly consist of pyritous diorites. On the Broken River and its tributaries an area having a breadth of thirty miles with a length of sixty miles, is occupied by a persistent outcrop of Devonian strata, in which gold has in no case been discovered in remunerative quantities except in a small gully heading from a ridge where a trap dyke has penetrated the Palæozoic rocks. Various districts, however, where Devonian rocks prevail, have at different times been centres of gold-mining enterprise, but, as far as is yet known, the country has, in every case, been traversed by dykes of diorite, diabase, or porphyrite. Tufaceous representatives of each of these rocks are sometimes also found interstratified with the upper portion of the same formation, and occasionally also throughout the other beds.

At Gympie, one of the richest quartz-mining districts in the colony, the auriferous area is confined either to veins traversing a crystalline diorite, or within a certain limit of its boundary marked by the presence of fossiliferous diabase tuffs.[1]

At one of the diggings near Peak Downs, water-worn gold occurs in a Carboniferous conglomerate containing *Glossopteris*, resting upon an underlying conformable shale abounding in the same fossil. Mr. Daintree was of opinion that the only reason that water-worn gold has not been more frequently found under similar conditions is explained by the fact that marine and lacustrine deposits, such as the Carboniferous as well as all the Mesozoic and older Cainozoic strata of the continent, are chiefly built up of sediments which have not been derived from the rocks on which they rest. Only beaches or locally filled fjords of Carboniferous or Mesozoic sea-coast, where auriferous reefs have cropped out and have had a chance of extensive abrasion, would, he considered, be likely to contain drifted gold.[2]

A large proportion of the gold obtained from Queensland is derived from shallow alluvial workings, some of which are mere washings of the gravels found in river-beds, which are collected from holes and crannies on the surface of the bed-rock. Although a great volcanic outburst, which is regarded as being contemporaneous with the upper volcanic series of Victoria, has overspread enormous areas with basaltic lavas, the working of deep leads below such flows is not extensively prosecuted. Quartz mining is, however, carried on with considerable activity, and the quartz treated is considerably richer than that of Victoria.

In the year 1880 the average yield of the 116,418 tons of auriferous quartz treated, amounted to 1 oz. 11 dwt. 12 gr. of gold per ton; the aggregate area of the gold-fields was estimated at 15,725 square miles; and 1,578 distinct quartz leads had been proved to be auriferous. Many of the quartz veins when enclosed in sedimentary rocks, traverse the planes of bedding at considerable angles, and are, therefore, entitled to be regarded as true veins.

From a report on the mineral resources of the district between the Charters Towers gold-fields and the coast, published in 1879,[3] we learn that gold in small quantities has been found in the gravel

[1] R. Daintree, "Notes on the Geology of the Colony of Queensland," *Quart. Jour. Geol. Soc.*, vol. xxviii. 1872, p. 292.

[2] "Note on certain Modes of Occurrence of Gold in Australia," *Quart. Jour. Geol. Soc.*, vol. xxxiv. 1878, p. 431.

[3] Robert L. Jack, "Report on the Geology and Mineral Resources of the District between Charters Towers Gold-fields and the Coast," Brisbane, 1879.

of the rivers on the coast side of the range. Areas occupied by recent alluvial deposits are met with at Brennan's Creek and Mossman's Creek, and another extends for some distance along Sandy Creek. Some narrow strips of alluvium on creeks to the south of Charters Towers have yielded considerable quantities of gold, but the narrow alluvial flats on many of the small streams have been almost completely worked out. Some of the tributaries of the Little Star River, more especially that known as Dry or Scrubby Creek, have for many years attracted a few miners, whose desultory labours have been on the whole fairly rewarded. The drift of the Little Red Bluff and the deep lead in connection with it, have been repeatedly tried for gold, but with very indifferent success; although the number of shafts sunk in the basalt sufficiently attests the earnestness with which the work was formerly carried on.

From an examination of the shafts which remained open at the time of his visit, Mr. Jack arrived at the conclusion that but few of them had reached the true bottom. The deep lead to the south-east of Millchester employed the labour of a considerable number of diggers in the year 1872, when a good many made considerable profits. Mr. Jack considers that in this district, generally, it would, in the first instance, be prudent to confine operations to leads in the vicinity of known auriferous reefs; and, for the benefit of intending explorers, quotes Daintree's observation, that it is doubtful if any marine or extensive lacustrine beds, except on their shingle margins, have produced or are ever likely to produce remunerative workings of free gold, for the simple reason that the majority of the sediments of which they are composed are derived from formations, the greater part of which were non-auriferous.

Over the whole of the Pre-Devonian metamorphic area, quartz reefs are numerous and the soil is strewn with quartz fragments; from which it is probable that some of the gold may have found its way into the various streams. Numerous dykes of diorite occur throughout the district, and copper and tin ores in considerable quantities have been obtained from the district north of the Burdekin.

The rich gold-field of Charters Towers occupies the western edge of an area of ordinary and syenitic granite, bordering on the little altered slates and grits of the Sandy Creek district. It is only when the reefs of this district are laid down upon a map that any idea can be formed of their general mode of arrangement. They are then found to diverge like rays, from a common centre to which they do not extend, and as there is a break of some 35°

in the circle, which commences about 10° east of north, a sort of horseshoe shaped figure is the result. The lodes thus radially disposed, when seen from near the point towards which they converge, dip in the eastern half of the circle, for the most part, to the left, while in the other half their inclination is usually to the right of the observer.

A large proportion of the reefs in the Charters Towers district are enclosed in granite, but they also sometimes occur in porphyry. The veinstone is principally quartz, containing iron pyrites and pyrrhotine, both of which are auriferous, but more particularly the latter; pyrites containing gold is also present in the clay selvages of some of the veins, but the amount is usually not sufficient to leave a profit on the process of extraction. As long ago as the year 1879 some of the quartz mines in this district had already attained a depth exceeding eighty fathoms.

The following table, compiled from official sources, shows the weight and value of the gold exported from Queensland from the beginning of 1861 to the close of the year 1882.

TABLE SHOWING THE WEIGHT AND VALUE OF GOLD, THE PRODUCE OF THE COLONY, EXPORTED FROM QUEENSLAND DURING THE FOLLOWING YEARS.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	oz.	£		oz.	£
1861	1,077	3,928	1872	186,019	660,396
1862	189	625	1873	194,895	717,540
1863	3,936	14,802	1874	375,587	1,356,071
1864	22,037	83,292	1875	391,515	1,498,433
1865	25,339	92,938	1876	374,776	1,427,929
1866	22,916	85,561	1877	353,266	1,307,084
1867	49,092	189,248	1878	283,592	1,052,490
1868	165,801	593,516	1879	281,552	1,023,237
1869	138,221	523,045	1880	228,120	820,643
1870	136,773	489,539	1881	259,782	925,012
1871	171,937	616,907	1882	230,090	829,665
			Totals	3,896,512	14,311,901

COPPER.—We are without detailed information relative to the mode of occurrence of copper ores in Queensland, but the range of this metal in the colony is very considerable, extending as it does from West Moreton on the south, up to the Cape York country in the north; and from the seaboard on the east, far back into the western regions. Among the known localities which have produced copper the following may be mentioned, namely ;—Peak Downs, Mount Perry, Copperfield, Mount Norma, Glen Prairie, Cloncurry, Kroombit, Edina, Cressbrook, Kennedy, Rawbelle, Mount Flora, Mount Orange, Mount Greentop, Charters Towers, Drummond, Boolboonda, Mount Harpur, Mount Gotthard, Ellandale, Great Blackall, Mount Clara, Teebar, Munna, Wolca, Normandy, &c.[1]

At the Peak Mine igneous and metamorphic rocks predominate, the Peaks giving the name to the locality being entirely composed of partially decomposed trachyte. An amygdaloidal dolerite sometimes contains patches of copper ore, and some of the cupriferous traps are said to very closely resemble those of the Lake Superior copper mines. As early as 1870, 29,168 tons of 20 per cent. copper ores had been raised from this property. About that period a lode two feet in width, running east and west, was cut at a depth of forty fathoms from the surface and traced for a distance of 250 fathoms. This discovery was followed in 1873 by that of another lode containing large quantities of black oxide of copper. In five years the dividends, on a nominal capital of £100,000, reached the sum of £215,250, besides which £53,577 had been written off the value at the mine. The company had, however, subsequently to contend with very serious difficulties; the land transport to the place of shipment was over 250 miles, and miners' wages ranged from three to four pounds per week. A decline either in the shipment of ore or in the price of copper, consequently, very seriously affected the undertaking, which was eventually closed. A mine has been worked at Mount Perry upon nearly vertical veins enclosed in granite, but the position of the locality with respect to the port of shipment renders the transport of ores very expensive.

Very large quantities of copper ore are said to occur in Palæozoic rocks at Cloncurry, which is however unfavourably situated with regard to transport, being on the western side of the main dividing range and 500 miles from the shipping port of Townsville.

At the Kennedy Copper Mine, near Sandy Creek, west of the Star River, the lode shows a large outcrop in porphyry, and courses about 35° east of north. At the Great Northern Copper Mine, in the Upper Star basin, a lode occurs in clay slate between two masses of granite. Only three copper mines are, at the present time, working in the colony.

[1] James Bonwick, "Resources of Queensland," p. 104; London, 1882.

The following table, compiled from official sources, shows the weight and value of the copper, copper ore and regulus, exported from Queensland, from the commencement of 1872 to the close of the year 1880.

COPPER, COPPER ORE AND REGULUS, THE PRODUCE OF THE COLONY, EXPORTED FROM QUEENSLAND DURING THE FOLLOWING YEARS.

Year.	Ingots.		Ore and Regulus.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£	Tons.	£
1872	2,886¾	234,540	1,043	23,183	3,929¾	257,723
1873	2,339¼	189,479	418	11,220	2,757¼	200,699
1874	1,766	146,038	136¾	3,658	1,902¾	149,696
1875	1,291	105,549	219	5,714	1,510	111,263
1876	2,056	170,881	46	1,501	2,102	172,382
1877	1,920	165,601	39	1,736	1,959	167,337
1878	490¾	32,825	83¾	2,301	574½	35,126
1879	499¾	32,641	67	2,150	566¾	34,791
1880	311¼	19,279	14¾	858	326	20,137
Totals .	13,560¾	1,096,833	2,067¼	52,321	15,628	1,149,154

During the year 1881 Queensland produced 3,220 tons of copper ore of the value of £5,520, while in 1882 the production amounted to 1,300 tons of the value of £13,000.

TIN.—Mr. T. F. Gregory was, in July 1872, sent to report upon the tin-fields at the Severn River, in the district of Darling Downs South.[1] He describes the stanniferous area of Queensland, as far as was then known, as being comprised within the following limits. "Commencing on the main dividing range between the eastern and the western waters at Lucky Valley Gold-fields, near the head of the Condamine River, the northern boundary extends in a west-south-westerly direction for about twenty-five miles, passing fifteen miles south of the town of Warwick to the head of Pike's Creek on the Pikedale Run; from this point it is bounded by a slightly curved line extending south about twenty miles to the Severn River, three miles below the Ballandean Head Station, where it trends south-east for twelve miles further, meeting the boundary of New South Wales at the Tenterfield Run; thence the crest of the watershed which forms the boundary between the two colonies, embraces it in a north-easterly and easterly direction, back to Lucky Valley, the area comprised being, in round

[1] *Quart. Jour. Geol. Soc.*, vol. xxix. 1873, p. 1.

numbers, five hundred and fifty square miles in extent. Of this area, however, only about two hundred and twenty-five square miles have hitherto been found sufficiently rich in tin ore to pay for working."

The physical and geological character of the whole of the area described is that of an elevated granitic table-land intersected by ranges of abrupt hills, the highest of which are about three thousand feet above the sea level; its eastern escarpment forms the watershed of the Clarence River, the northern that of the Condamine, and the south-western that of the Severn and McIntyre Rivers. The richest deposits have been found in stream beds and in fluviatile flats on their banks, the productive ground varying from a few yards to five chains in width but occasionally broken by rocky bars. In such cases large deposits are frequently lodged in the spaces existing between the various granitic boulders. The aggregate length of these stanniferous bands was estimated by Mr. Gregory at about one hundred and forty miles on the Severn River, and about thirty more on the tributaries of Pike's Creek. At the date of Mr. Gregory's report, the tin lodes which had been discovered were but very imperfectly tested.

The discoveries of tin ore made about the end of 1879 and the beginning of 1880, in the Wild River and Great Western districts, have, however, entirely eclipsed all previous ones.

The Herberton Tin Mines are situated on the slopes and crests of spurs from a great granitic mountain range, which runs nearly north and south at a distance varying from forty to fifty miles from the coast. The tin claims are chiefly on the slopes of the mountains which, at a distance of less than a mile, entirely surround the town. The summit of the range is on an average from six to seven hundred feet above the level of the Wild River.

According to the Rev. J. E. Tenison-Woods,[1] the workings are of three kinds:—

First, those in which the tin ore has been scattered on the surface of slopes beneath, and in the immediate vicinity of, a lode. The second kind of workings consists in quarrying out masses of tinstone occurring on the backs and outcrops of lodes. Such bunches are due to the retention, in its original position, of the cassiterite present in the veins; while the lighter impurities, with which it was originally associated, have been removed by disintegration and the mechanical action of water. The third class

[1] Rev. J. E. Tenison-Woods, "Report on the Wild River and Great Western Tin Mines (near Herberton)," Brisbane, 1881.

of workings consists of ordinary mining, where shafts are sunk and levels driven.

As far as they have been hitherto explored, the lodes in this neighbourhood are both wide and exceedingly rich. They vary to some extent in their direction and dip, but are commonly nearly vertical. At Herberton the average direction will be somewhat east of north and west of south; but on the western side of the granitic range the average direction is, on the contrary, more frequently west of north and east of south.

The Herberton mines are on the Wild River, and on the eastern side of the granite range; but on the western side, at a distance of between six and seven miles, on the sources of the Tate and Wash Rivers, there is a second stanniferous area, known as the Great Western tin-field. The granites of both regions are essentially composed of orthoclase, quartz, and black mica, and the tin ore is sometimes accompanied by wolfram.

A peculiar feature of the metalliferous deposits of the Great Western area is the outcrop of several copper lodes, which sometimes carry rich ores. The following description by Mr. Jack of one of the localities which he visited, will serve to convery some idea of the general richness of the deposits in this district.[1]

"Prospectors' Gully falls west-north-west into the Wild River. At the date of my visit the greater part of the bottom had been cleaned for about 1¼ mile up the gully and the wash-dirt stacked ready for sluicing. Here and there lay groups of boulders of tin ore gathered out of the wash-dirt; many of them nearly 100 lbs. in weight. These large boulders stopped about a quarter mile up the gully below a reef of quartz showing tin ore in large lumps, which is seen on the right bank of the gully striking S. 10° W. to N. 10° E. The wash-dirt in the gully above this lode is characterised by finer stream tin.

"Shortly above the lode the gully splits into three branches. Between the southmost and middle branches, lumps of ore, from the size of marbles to the size of eggs, strew the surface in astonishing quantities. Without moving from the spot one might easily gather a stone weight of ore almost anywhere by reaching out his two hands. The whole of the 'surface' here should pay well to wash. This surface ore leads up to the Great Northern Lode of the Prospectors. A shaft has been sunk on this to the depth of six to ten feet. Twenty-six tons of ore, containing 60 per cent. of tin have been raised from this shaft and sold."

[1] R. L. Jack, *Geol. Survey of Northern Queensland*, 1881, p. 8.

Observations made during this examination led Mr. Jack to the conclusion that the tinstone was originally in the form of disseminated crystals, which have become concentrated by the weathering of their matrix during a long period of sub-aerial denudation. Two distinct types of tin-bearing rock were met with, namely, quartz reefs, and eruptive dykes. Many of the latter are to be passed at various points along the rocks on the boundary between Queensland and New South Wales.[1]

The number of tin streams and tin mines in operation in the colony during the year 1881 amounted to 174, but no deep leads appear to have been worked under the basalt. On referring to the following table the enormous increase in the production, consequent upon the discovery of the Wild River and Great Western tin deposits, cannot fail to be observed.

AMOUNT AND VALUE OF TIN ORE PRODUCED IN QUEENSLAND FROM 1872 TO 1882 INCLUSIVE.

Year.	Tin Ore.	
	Quantity.	Value.
	Tons.	£
1872	1,383	96,840
1873	3,790	208,993
1874	3,193	160,592
1875	2,470	103,740
1876	2,325	102,030
1877	2,519	94,462
1878	1,178	35,340
1879	3,142	106,010
1880	1,553	47,300
1881	106,448	2,168,790
1882	27,312	560,590
Totals	155,313	3,684,687

During the year 1882 Queensland exported 418 tons of argentiferous lead ores, representing a value of £6,479.

SOUTH AUSTRALIA.

Mining operations have, for many years, been extensively carried on in various parts of South Australia, the most important minerals hitherto found being ores of copper. Gold, although to

[1] *Proceedings Royal Geogr. Soc.*, vol. v. 1883, p. 101.

some extent present in the majority of its rivers and streams, is by no means abundant. With regard to the mode of occurrence of argentiferous lead ores, which have been produced in considerable quantities, we are without detailed information. Until within a very short time South Australia has been without a Government Geologist, and consequently but little is accurately known of its geology; while with regard to its mineral productions we have scarcely any information beyond that supplied by various statistical tables.

GOLD.—Mr. G. H. F. Ulrich, who visited South Australia in the year 1872, describes the principal localities in which gold mining was then being carried on; the most important gold-fields being the Ulooloo, the Blumberg, the Barossa, and the Echunga, but gold was also obtained at the Jupiter Creek Diggings and elsewhere.[1]

The Ulooloo gold-field is situated some twenty-five miles north of the celebrated Burra Burra Mine, within an area forming part of the extensive northern region which has been proved to be rich in copper ore, but in which the existence of gold was at one time thought doubtful. The rocks throughout this portion of the field consist of flaggy, grey, brown, and bluish slates, alternating with massive quartzites and gritty sandstones. All these rocks are traversed by quartz veins, apparently in all respects similar to those met with several hundred miles further north, which have been regarded as exhibiting an auriferous aspect. Unfortunately, however, the non-discovery of fossils in the rocks of either of these localities precludes the possibility of establishing their geological relations. This field contains numerous deposits of auriferous shingle brought down from the surrounding ranges, and these may be divided into two classes.

The more recent deposits are shingly drifts occupying the beds of creeks which have been for the most part eroded to the depth of several feet in slaty rocks, and, as the surfaces of these gullies are generally rendered very uneven by joints and fissures along cleavage planes, the collection of the wash-dirt becomes a slow and troublesome operation. The older deposits, on the other hand, form banks of from 6 to 20 feet in depth, chiefly composed of clay, sand, and shingle, lying between the principal and branch creeks. These are generally richer in gold than those belonging to the other class. The principal diggings at Ulooloo extend for a distance of about a mile up a main branch of the creek, and the slightly water-worn character of the gold found

[1] "Mineral Resources North of Port Augusta," p. 19, Adelaide, 1872.

would appear to indicate that the reefs whence it was originally derived cannot be situated at any considerable distance.

The rocks of the Blumberg gold-field are partly of an eruptive and partly of a metamorphic character. They consist of mica schist, hard micaceous quartzites, sandstones, and flagstones, and are traversed by eruptive dykes and by protrusions of a very coarse-grained granite characterised by containing large crystals of white mica. The alluvium here varies from three to five feet in thickness, and at the surface consists of brown and yellow mottled sands and clays, beneath which is a layer of from one to two feet in thickness, consisting of a mixture of clay and angular quartz-gravel resting on a soft bottom composed of mica schist. Wherever this thins out, the surface is, as a rule, found remuneratively auriferous up to a spot covered with numerous loose blocks of quartz. The gold is throughout of a crystalline spongy character, and must have been derived from reefs in close vicinity to the diggings. Some of the samples of alluvial gold from this field resemble the so-called spider-leg gold from the northern gold-fields of Queensland, which there occurs not only in the drifts but also in elvan dykes and greenstone. In this district various quartz reefs have from time to time been worked, but not generally with satisfactory results.

The Barossa gold-field is said to exhibit in its topographical and geological features a close resemblance to some of the Victorian fields where the protective covering of basalt is absent. The principal deposit is probably of Pliocene age, consisting of rounded quartz pebbles, and boulder drifts, enclosing layer-like patches of ferruginous quartzose conglomerate. Both the older and more recent drifts are auriferous; but various circumstances go to show that the gold in the latter was mainly derived from the disintegration of the former. From the fact that a portion of the gold found in the more recent alluvium is less water-worn than is that from the older, there is a probability that auriferous quartz reefs exist within the limits of this gold-field.

At Echunga the geological features of the country closely resemble those occurring at Barossa, namely a drift of probably older Pliocene age, composed of rounded quartz pebbles, ordinary drift, and conglomerate, occupying the slopes and summits of tolerably high ranges. Some of the quartz leads in this gold-field have been rather extensively prospected.

At least a portion, if not the chief part, of the gold found in Jupiter Creek has likewise been derived from denuded older drifts, as is shown by rich cemented cakes and surface patches composed of rounded quartz pebbles, worked on the hill side. Since the gold in the gully is either hackly or only slightly rounded, and as specimens of auriferous quartz are of frequent occurrence, there can be little doubt that one or more quartz reefs must exist somewhere near the head of the gully.

Mr. J. A. Plunkett states that, although a large amount of money has been expended in quartz reefing in the northern territory, and a good deal of quartz has, in the aggregate, been raised and crushed, quartz mining has not been fairly tried. Many claims have been superficially tested, while not a sufficient number of them has been systematically worked. The average yield from the commencement would, however, he believed, exceed one ounce of gold per ton of stone crushed.[1]

The principal reefs to which attention has been directed, taking them in order from north to south, are the following:—The Stapleton Reefs, the Howley Reefs, the Britannia Reef, the Yam Creek Reefs, the Extended Union Reef, the Union and Lady Alice Reefs, and the Pine Creek Reefs. Of these the Union and the Lady Alice Reefs, with the Pine Creek Reefs, are the only ones which have been worked upon anything like an extensive scale. With the exception of one or two reefs which run nearly due north, their course is either north-westerly or north-north-westerly, and in some cases they can be traced for a considerable distance.

In the year 1875 the total result obtained from thirty-three distinct crushings of quartz from the northern territory of South Australia was as follows:—

Quartz treated, 2,732½ tons; gold obtained, 4,327 oz. 18 dwt., a little more than 1 oz. 12 dwt. of gold per ton of stone treated.

No detailed statistics of the gold production of South Australia appear to have been officially published, but it is semi-officially stated that up to 10th December, 1881, 130,000 oz. of gold, valued at £450,000, had been exported from the colony.

COPPER.—The history of copper mining in South Australia dates from the year 1843, when the Kapunda Mine was discovered on a sheep run, fifty miles north-east of Adelaide. Smelting for regulus was commenced in 1849, and the process was subsequently extended to the manufacture of fine copper. The Burra Burra Mine was discovered about two years after the Kapunda, from which it is distant some forty-eight miles in a northerly direction. The total quantity of ore raised from the Burra Burra

[1] "South Australia," edited by William Harcus, p. 169, London, 1876.

Mine during twenty-one years from its commencement was 215,132 tons, giving an average produce of 22 per cent., and worth over £4,000,000. For some years, however, the yield of ore from this mine has been comparatively small.

There are two lodes at Burra Burra, both striking north-west and south-east and dipping north-east at an angle of about 70°. The rock forming the foot wall of Allen's Lode is a "serpentinous limestone," massive and compact; while the rock on the hanging side of Kingston's Lode is composed of very thin, highly inclined beds of non-fossiliferous limestone. The veins would seem to come under the class known as contact veins, but as no workings were made south of their junction, and no section of the country rock exists, the evidence on this point cannot be regarded as complete. The main engine shaft is sunk to a depth of 100 fathoms from the surface, and there is no adit. Blue and green carbonates continued to a depth of from forty to fifty fathoms. Red and other oxides of copper as well as metallic copper were also found more or less within these limits. Between the 50- and 60-fathom levels large "horses" occurred containing vein material and ore. A little below the 70-fathom level erubescite was found, while between the 90- and 100-fathom levels the first discovery of copper pyrites was made.[1]

For many years the Burra Burra was probably the richest copper mine in the world, but, in 1860, the discovery of the Wallaroo Mine, Port Wallaroo, and shortly after of the Moonta Mine, on Yorke's Peninsula, within the next two years brought formidable rivals into the field. The development of the Wallaroo Mines was exceedingly costly, and a large amount of capital, amounting to some £80,000, was expended before any adequate returns had been made. Since the year 1860 its progress has however been satisfactory, the lodes being in many places extraordinarily large and productive; sometimes measuring nearly thirty feet in width of almost solid ore, containing 12 per cent. of copper, and yielding as much as sixty tons of ore per running fathom. The width of the lodes is, however, usually from five to ten feet.

There are three distinct lodes at the Wallaroo Mines, all of which are enclosed in porphyrite. They strike about 20° S. of E. and are nearly perpendicular down to the 80-fathom level. These lodes consist of a series of large lenticular masses connected by narrow partings in the country rock. There are many cross

[1] MS. notes furnished by Mr. J. Darlington.

divisions against which the ore often terminates, as well as others which slightly shift the lodes. The principal ores to a depth of 15 fathoms are carbonates of copper; black sulphides between the 15- and 25-fathom levels; and copper pyrites from the 25-fathom level downwards. The porphyrite, which is the country rock, is often capped by limestone, and the ores on an average assay about 12 per cent. for copper.

During the first fifteen years after the opening of the Wallaroo Mine the total quantity of ore raised was 290,669 tons, each of 21 cwts.

About a year subsequent to the discovery of the Wallaroo Mine, a still more valuable find of copper ore was made eleven miles to the south-west of it, and about two miles from the coast. A quantity of small fragments of green carbonate of copper having been found lying on the surface of the ground, pits were sunk, and a fine lode of copper ore was met with at a very inconsiderable depth. This was the commencement of the now celebrated Moonta Mine. At this mine highly inclined masses of porphyrite are covered by a layer of conglomerate, varying from one to three feet in thickness. On this reposes a bed of stiff red clay resulting from the decomposition of porphyrite, between four and five feet in depth, covered by two feet of limestone, above which are a few inches of sand and gravel. The principal lodes are three in number, namely: the Main Lode coursing 20° N. of E., with an underlie of from two to three feet per fathom west; Young's Lode, with a direction 40° E. of N., and an underlie of from three to five feet in a fathom west; and Dominick's Lode, coursing 40° E. of N., and underlying from four to five feet per fathom west. The distance between Young's Lode and the Main Lode is from 800 to 900 fathoms, and between the former and Dominick's Lode from 70 to 80 fathoms. Other lodes are sometimes recognised, but it is probable that they are all either branches or prolongations of the above. The average yield of the dressed ore is about 18 per cent. During the first twenty months after the opening of the Moonta Mine, 8,000 tons of ore, averaging nearly 25 per cent. of fine copper, were raised, and dividends amounting to £64,000 were paid from the proceeds. The average yearly return from the commencement up to 1876 was 18,220 tons of ore, of an average yearly value of £197,270. There are various other mines in the neighbourhood of the Moonta, which have been worked with more or less successful results.

Copper mines have been opened in two or three localities near the River Murray; and at Callington, about thirty-six miles from Adelaide, in the direction of the Murray, a copper mine has been working for many years with a moderate degree of success. A few miles from this is the Huel Ellen Mine, situated about three miles from the town of Strathalbyn, which was originally worked for argentiferous lead ores. The lead ore ultimately gave place to oxide of copper; but the mine is believed to be at present unworked.

The most extensive mineral district of the colony is that lying north, north-east, and east of Port Augusta. Here the unaltered sedimentary rocks composing the tract of country from the Burra Burra Mine northward, show as a whole a remarkable uniformity in their lithological characters. The same rocks, consisting of quartzites, slates, and shales of various textures, sandstones, conglomerates, and siliceous limestones, recur again and again in grand anticlinal and synclinal undulations over hundreds of miles. As no traces of organisms have anywhere been found in these strata, the geological age of the rocks has not been accurately determined, but Mr. Ulrich, who visited this region in 1872, unhesitatingly assigns them to one of the older epochs of the Palæozoic period. As a rule, this region has the disadvantage of being barren and comparatively waterless. Timber for mining purposes is absent, and communication with the seaboard is difficult and expensive.

In this area copper ores occur as impregnations, in pockets, in layers, and in lodes of various kinds, but, speaking generally, Mr. Ulrich does not appear to have formed a high opinion of its capacity as a mining district.

There were nineteen copper mines in operation during the year 1881, namely:—Yudanamutana; Blinman; at Dora; the Devon Consols Co.; the Hamley Mining Co.; at Kapunda South; at Moonta; the Wallaroo Co.; the Yorke's Peninsula Mining Co.; the Huel Friendship Mine; the Kunamundoo Mine; the Garrett Mine; Leigh's Creek; Nildotte; Beltona; Voca Vocina; Gammon's Creek; Mount Rose, and North Mount Rose. Copper ores are the most important minerals of South Australia, and upon the yield of its copper mines the prosperity of the colony to no small extent depends.[1]

The following table, compiled from official sources, shows the weight and value of the copper, copper ore, and regulus, exported from South Australia from the commencement of 1856 to the end of 1881.

[1] "The Australian Handbook," p. 373, London, 1883.

TABLE SHOWING THE QUANTITY AND VALUE OF COPPER, COPPER ORE, AND REGULUS, THE PRODUCE OF THE COLONY, EXPORTED FROM SOUTH AUSTRALIA DURING THE FOLLOWING YEARS:—

Year.	Ingots.		Ore and Regulus.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons cwts.	£	Tons	£	Tons cwts	£
1856	2,219 0	248,460	9,539	159,205	11,758 0	407,665
1857	2,844 13	290,739	8,115	144,245	10,959 13	434,984
1858	2,389 16	250,042	6,851	109,040	9,240 16	359,082
1859	2,837 5	289,841	7,447	107,399	10,284 5	397,240
1860	3,271 9	331,775	8,335	104,007	11,606 9	435,782
1861	3,052 7	294,572	8,207	152,874	11,259 7	447,446
1862	4,293 12	400,591	6,634	143,781	10,927 12	544,372
1863	4,802 0	477,944	5,382	84,917	10,184 0	562,861
1864	6,702 15	637,791	4,597	40,605	11,299 15	678,396
1865	5,009 16	433,795	16,176	184,677	21,185 16	618,472
1866	6,463 12	584,509	16,824	225,683	23,287 12	810,192
1867	7,843 3	627,384	11,455	113,969	19,298 3	741,353
1868	5,211 7	400,691	20,735	207,732	25,946 7	608,423
1869	4,639 8	371,566	26,835	250,259	31,474 8	621,825
1870	5,471 1	394,919	20,886	173,861	26,357 1	568,780
1871	6,395 11	518,080	20,127	119,903	26,522 11	637,983
1872	7,452 10	680,714	26,964	122,020	34,416 10	802,734
1873	7,087 4	635,131	27,382	133,371	34,469 4	768,502
1874	6,629 7	557,306	22,854	136,530	29,483 7	693,836
1875	6,841 15	578,065	26,436	175,101	33,277 15	753,166
1876	5,463 9	427,403	22,682	164,597	28,145 9	592,000
1877	5,143 11	396,602	18,532	165,408	23,675 11	562,010
1878	3,594 6	252,206	17,007	155,381	20,601 6	407,587
1879	3,368 10	217,186	13,715	134,202	17,083 10	351,388
1880	3,255 8	233,374	14,622	112,773	17,877 8	346,147
1881	3,824 5	263,370	21,638	154,926	25,462 5	418,296
Totals...	126,107 0	10,794,056	409,977	3,776,466	536,084 0	14,570,522

LEAD.—The mines of argentiferous galena are for the most part situated in the southern portion of the colony near Cape Jervis. Among the most important are the Talisker, George, and Campbell's Creek Mines. Lead ores have also been found near Kapunda; and several years ago galena was found in the hills twenty miles south-east of Adelaide.

The following table shows the quantity and value of the lead and lead ore annually exported from South Australia during twenty-six years. A considerable proportion was the produce of the Huel Ellen Mine, near Strathalbyn, but we are without any detailed information relative to the mode of occurrence of lead ores in that district.

TABLE SHOWING THE QUANTITY AND VALUE OF LEAD AND LEAD ORE, THE PRODUCE OF THE COLONY, EXPORTED FROM SOUTH AUSTRALIA FROM 1856 TO 1881 INCLUSIVE.[1]

Year.	Lead.		Lead Ore.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons cwts.	£	Tons cwts.	£	Tons cwts.	£
1856	—	—	33 0	377	33 0	377
1857	—	—	1,422 0	23,855	1,422 0	23,855
1858	—	—	853 0	14,200	853 0	14,200
1859	63 1	5,710	262 0	8,068	325 1	13,778
1860	91 4	8,275	68 0	2,480	159 4	10,755
1861	62 16	4,426	15 0	300	77 16	4,726
1862	21 6	981	97 0	2,260	118 6	3,241
1863	13 11	525	450 0	9,007	463 11	9,532
1864	3 3	121	566 0	13,107	569 3	13,228
1865	4 2	133	86 0	1,507	90 2	1,640
1866	67 11	2,991	648 0	11,318	715 11	14,309
1867	169 11	5,464	212 0	3,353	381 11	8,817
1868	152 9	5,670	76 0	1,245	228 9	6,915
1869	146 16	4,471	24 0	296	170 16	4,767
1870	128 4	4,089	3 0	21	131 4	4,110
1871	169 1	5,497	—	—	169 1	5,497
1872	—	—	61 0	2,324	61 0	2,324
1873	14	20	—	—	14	20
1874	—	—	24 0	332	24 0	332
1875	—	—	132 0	66	132 0	66
1876	11	14	17 0	215	17 11	229
1877	18 11	295	6 0	120	24 11	415
1878	—	—	—	—	—	—
1879	3 0	90	—	—	3 0	90
1880	—	—	—	—	—	—
1881	—	—	90 0	1,182	90 0	1,182
Totals.	1,115 11	48,772	5,145 0	95,633	6,260 11	144,405

OTHER METALS.—Stibnite occurs in South Australia, and from 1865 to 1875 390 tons of bismuth ore, of the value of £14,700, were shipped from the colony.

The annexed statement shows the amount and value of zinc exported during four years.

WEIGHT AND VALUE OF ZINC EXPORTED FROM SOUTH AUSTRALIA DURING THE FOLLOWING YEARS:—

Year.	Weight. Tons cwts.	Value. £
1878	39 11	937
1879	43 12	1,401
1880	34 10	1,091
1881	9 0	200
Totals	126 13	3,629

[1] From the values affixed it is evident that the lead and lead ores must have been argentiferous, and probably also contained gold.

Western Australia.

Although small patches of more or less auriferous drift occur in various localities scattered over this portion of the Australian continent, gold has not as yet been anywhere discovered in paying quantities. Among other places it occurs at Peterwangy, in alluvial detritus, the bed-rock consisting of granulite intersected by trap dykes, and towards the lower ground overlain by beds of nodular ironstone, sandstone, and grit. The result of prospecting in this place was the discovery of some minute specks of gold in quartz enclosed in greenstone. Quartz veins, varying from the width of a sheet of paper to several feet in thickness, are found traversing the older rocks wherever they reach the surface, but do not extend into the more recent formations. The quartz enclosed in granite is usually more transparent than that of veins traversing sedimentary rocks, which frequently bears a close resemblance to the veinstone of the auriferous reefs of Victoria, and often contains considerable quantities of iron pyrites. The general strike of these veins varies from north and south to north-east and south-west, in which directions they may sometimes be traced for long distances.

In the Champion Bay district both lead and copper ores have been found in gneissic rocks associated with granite, greenstone, &c., and have, in some cases, been followed to depths from the surface exceeding fifty fathoms. The general indications pointing to the presence of a lode are the occurrence of dykes of diorite or felsite, by which the metamorphic rocks have been fissured and faulted, accompanied by segregations of quartz and outcrops of pulverulent gossans. It is only at certain points, however, along the course of a lode that the veinstone reaches the surface, as a covering of soil frequently hides the rocks from view, and, generally speaking, lodes have not been prospected for, where no fragments of ore had been previously picked up on the surface. According to Mr. H. Y. L. Brown, whose report was published in 1873, ten mines had, previous to that date, been opened in this district for copper and lead, but of these only two, the Geraldine and the Oakajee, were then in operation.[1]

The chief cause of the abandonment of many of these mines was want of capital, and unskilful working. From a consideration,

[1] "General Report on a Geological Exploration of that portion of the Colony of Western Australia lying southward of the Murchison River, and westward of Esperance Bay," Perth, 1873.

however, of the numerous outcrops of ore at the surface, the number and size of the veins met with, and the amount of ore raised at very moderate depths, he is inclined to believe that this district affords an advantageous field for the judicious employment of capital.

The following information with regard to the depth of the lowest workings and the quantity of ore raised, was all that Mr. Brown was enabled to gather from authentic sources:—

Name of Mine.	Deepest Level.	Ore in Tons.		Date.	Value at Swansea.
		Lead.	Copper.		
	Feet.				£
Huel Fortune . .	300	2,475	985	1862 to 1868	
Geraldine . . .	320	1,634	—	Nov. 1869 to Dec. 1870	
Tanganooka . .	108	—	458	—	5,881
Gwalla	200	—	901	—	16,573
Wanerenooka . .	180	—	—		
Gelira	100	—	300		

The total amount of lead ore exported from 1860 to 1865 was 1,363 tons. The amount of copper ore exported during the same period was 4,500 tons. In the month of April 1881, seven lead mines were working in the Victoria district of Western Australia, the production for the year previous having been 1,430 tons of ore, valued at £10,579. There was also one copper mine in operation which, during the same year, yielded one ton of copper ore, valued at £15.

TASMANIA.

In addition to coal, anthracite, and iron ores, Tasmania produces gold, tin, and bismuth, besides which galena and copper ores have, in limited quantities, been found in various parts of the island. Coal and iron ores are especially abundant, a large deposit of the latter at Ilfracombe, eight miles from the River Tamar, being described as yielding a brown hæmatite of exceptionally good quality. The mineral resources of the colony were for many years somewhat neglected, but it is now divided into six mining districts and a Department of Mines has been established. Mining enterprise in Tasmania received a great impetus at the end of 1872, by the discovery of extensive deposits of tin ore at Mount

Bischoff, in the north-west portion of the island. Tin has since been found distributed over a considerable extent of country, near the north-east corner of Tasmania, and has now become one of its most important productions.

GOLD.—Gold is obtained both from recent alluviums and from quartz reefs; auriferous tertiary drifts, believed to be of Pliocene age, also occur, but hitherto they have not been very extensively worked, although batteries have been erected for the treatment of cement. The auriferous regions embrace the following localities—The Pieman River, the Hellyer Diggings in the bed and on the banks of the river of that name, Anderson's Creek, Beaconsfield, Lefroy, Back Creek Diggings, Leura, Piper's River, Denison Diggings, Waterhouse, Mangana, and the Black Boy gold-fields.

In 1881 the yield of gold from placer washings was 10,917 oz., valued at £41,945, an average of £3 17*s.* 11*d.* per oz. During the same period 38,043 tons of quartz were crushed, yielding 45,776 oz. of gold, valued at £174,956, or £3 15*s.* 10¾*d.* per oz., making an average of 19 dwt. 13½ gr. per ton of rock treated.

TIN.—Mount Bischoff, where discoveries of tin ore were first made, is situated in the north-western portion of the island, and is distant, by the present route, fifty-four miles from the port at which the ore is shipped. Its vicinity, generally, is covered with thick forests of myrtle, while the summit of the mountain, where the tin principally occurs, is so densely shrouded by an almost impenetrable jungle that even an approximate estimate of the area of the stanniferous ground becomes somewhat difficult.

According to Mr. S. H. Wintle,[1] Mount Bischoff has an altitude of about 3,500 feet above the sea, and is but little more than 1,000 feet above the surrounding basaltic table-land, the ascent from the coast being somewhat gradual. The rock consists of an eruptive eurite-porphyry, which forms a crescent-shaped ridge at the summit, of which the extremities are not more than a quarter of a mile apart, the intermediate space thus forming a horse-shoe-shaped basin-like depression. It is here that the richest deposits of tin ore occur. This basin looks towards the south, and presents a natural outlet to the surrounding table-land, while the northern and western slopes are exceedingly steep, forming, on an average, an angle of 35° with the horizon. The porphyry, which is the chief matrix of the tin ore, has burst

[1] "Stanniferous Deposits of Tasmania," *Trans. Roy. Soc. of New South Wales*, vol. ix. 1875, p. 87.

through transition strata reposing on the slopes of the mountain displacing, contorting, and folding them in a most fantastic manner These strata chiefly consist of clay slate, sandstone, and other quartzose rocks, the former being frequently charged with iron pyrites and stannite. The tin ore (cassiterite) traverses the porphyry in strings and lodes, the breaking up of which, subsequent to the decomposition and disintegration of the surrounding porphyry, has probably been the cause of an accumulation of tinstone on the slopes of the mountain in the form of talus. The ore is not equally distributed over the surface, but is generally found accumulated in patches of limited extent. In illustration of this fact it may be mentioned that on one section 240 tons of tin ore were taken from an area of wash-dirt only sixty-six feet square, while at a distance of twenty yards on either side of the cutting scarcely a trace of tinstone could be found. Some of the masses of ore taken from the dirt on this claim weighed as much as six cwts., and not a few of them were almost entirely free from matrix. It appears somewhat remarkable that only one well-defined lode had, up to the beginning of 1875, been laid bare in this district, although surface mining had then been in active operation for more than two years.

Although the porphyry is the chief source of the ore, there are also rich deposits consisting of tin ore and hydrated oxide of iron, in which a face has been opened up to a depth of 30 feet. Ascending the slope of the basin in the direction of the top of the mountain, the tin ore, iron ore, and sand assume a cemented condition, and finally, at the summit, appear in cliff-like masses of conglomerate composed of a mixture of oxide of tin, iron oxide, and silica, sufficiently hard to require blasting. So rich in tinstone is this formation that blocks weighing several cwts. of nearly pure tin oxide may sometimes be broken from it. This deposit, which is known as the North Lode, can be traced for a distance of about half a mile. Small grains of native copper have been found associated with the ferruginous tin ore, while rich argentiferous galena and sulphides of antimony and zinc occur in adjoining claims. The galena is accompanied by a gangue of fluor spar and carbonate of iron, but the only veinstone associated with stibnite and blende is fluor spar.

That Mount Bischoff has been subjected to much dislocation is evident from an extensive line of fault running north and south, by which the whole of the eastern side of the mountain has been depressed, thus producing a line of vertical cliffs in some places more than 100 feet in height, which affords a fine section both of the intrusive porphyry and of the contorted sedimentary strata. It is said to rain at Mount Bischoff three days out of every four, the result being that all vegetation, as well as the numerous boulders on the surface of the ground, are thickly covered with moss. The gradual decay of these mosses has produced a stratum of peat often five feet in thickness, which constitutes the only "stripping" of the miner, as the tin ground lies immediately beneath it.

Mount Ramsay, which is situated at a distance of about ten miles from Mount Bischoff, attains an altitude of over 4,000 feet, and is essentially composed of a coarse-grained schorlaceous granite which occasionally passes into a fine-grained rock. This granite rises in the form of three lofty peaks, and, unlike Mount Bischoff, the older Palæozoic strata are only to be seen mantling around its base. The tin which is here found does not occur in such large quantities as at the last-named locality, but Mount Ramsay is well known for a large and rich vein of bismuth, which when first discovered was mistaken by the miners for tin in a native state.

Tin ore also occurs at Wombat Hill, about midway between Mount Bischoff and Mount Ramsay, and at Mount Housetop, twenty miles from the north-west coast of the island, where, in both instances, it is found in granite. The cassiterite is sometimes associated with zircon and pleonaste. On the east coast a rich deposit of stream tin occurs near the source of a small river known as the Golden Fleece, and the stanniferous district extends in a south-easterly direction as far as Falmouth and the Mount Nicholas Range. More recent discoveries show that a tin-bearing country exists for a great distance towards the north-west, as for instance at Boobyalla, Mount Cameron, Mount Horror, and in the Ringarooma district or Gould's new country. In 1876 the value of tin ore and ingots exported from Tasmania was £100,000; in 1877 it was £296,941; in 1878, £316,311; in 1880, £341,736, and in 1881, £375,775.[1]

OTHER METALS.—A lode of bismuth, then stated to be one of the richest in the world, was discovered some years since at Mount Ramsay, and another containing stibnite was met with in the Waratah Company's claim. Argentiferous galena has been found at the Penguin, and also in the neighbourhood of Mounts Roland and Claude, while copper ore occurs near Campbelltown. About 1,500 tons of ironstone were raised during the year 1881.

[1] "The Australian Handbook," p. 508, London, 1883.

New Zealand.

A considerable proportion of the population of New Zealand is occupied in gold mining, which, during the last twenty years, has been one of the most important industries of the colony. Ores of various other metals, such as copper, silver, lead, and mercury, although known to occur in various localities, have not hitherto been extensively worked.

Gold.—According to a memoir by Dr. A. Soetbeer[1] about 1,000 oz. of gold were obtained at Cape Coromandel, upon the eastern side of the North Island, in 1852, after which the workings were virtually abandoned. Four years subsequently gold mining was commenced in the province of Otago, in the South Island, and in 1861 a large increase in the gold production took place consequent on the discovery of rich deposits in the Tuapeka River, and at the Thames gold-fields. The North Island, although containing a large number of known quartz reefs, has produced less gold than the South Island, which is much richer in alluvial deposits. Its most important districts stretch on the western slope of the mountains, from Otago on the south, through the Westland gold-fields to those of North-west Nelson on the north.

The auriferous drifts of New Zealand occur in three distinct forms:—Firstly, as modern alluvium in the beds of streams and rivers; secondly, as more ancient deposits often occupying the sides of valleys; thirdly, as sands upon the seashore, where, by the constant action of the waves, a process of continuous concentration is in progress. The deposits belonging to the first class are of the ordinary kind, and exhibit no peculiarities to render a special description necessary. Deposits of the second class are sometimes of great thickness, many of them being regarded as belonging to the lowest Tertiary deposits of the colony. They are frequently so consolidated as to form a compact cement, and are then stamped and treated in the same way as gold quartz. When not so cemented they are often worked by the Californian process of hydraulic mining, for which facilities are afforded by the Government, which has, in some cases, brought in the necessary water, which is supplied to the miners at a fixed charge.

Some remarkable deposits of auriferous cements are worked at the Blue Spur, in the Otago district. The Blue Spur cements are enclosed in a trough, or more correctly, a basin, since, in addition

[1] "Edelmetall-Produktion und Werthverhältniss zwischen Gold und Silber," published as an extra number of *Petermann's Mittheilungen*, 1879.

to the bed-rock on which they rest as in a trough, the schists to the north-west and south-east rise in the form of hills which have a greater elevation than is at present assumed by the cements themselves. The bed-rock on the north-east side of the basin is very steep, while on the opposite one it is more shelving; the total thickness of the cements is regarded by the officers of the Geological Survey as being at least 300 feet.

An enormous quantity of this Spur has been worked away, so that what remains has been cut into deep gutters, and where sluicing or other claims have been for a long time in operation large masses of the hill have been removed. The Spur, therefore, which must formerly have possessed a configuration similar to that of the surrounding country, now presents a series of lofty pinnacles and steep cañons, bearing testimony to the large amount of work which has been done.[1] As a rule the rivers of New Zealand have extensively eroded their beds since the formation of the older alluvium, so that the deep leads, which often in other countries can only be reached with great trouble and expense, are here exposed in the declivities of valleys. No deep leads appear to be worked under a capping of basalt, as is the case in Australia and California, and the extension of the gold districts among the more recent volcanic rocks appears to be comparatively small.

The auriferous sands on the seashore, forming the third class of deposit, are worked by persons known as "beach combers," who wash them by the aid of fresh water brought through a canvas hose-pipe, upon movable sluices, called "beach boxes," one end of which is mounted on wheels for convenience of transport. Beaches are often unworkable for months together, since gold in remunerative quantities is only found upon them after the occurrence of high winds and heavy seas.

According to Ulrich the rocks in which auriferous reefs occur, or in which gold has been found in its natural matrix, in the province of Otago, excepting in the neighbourhood of Portobello, consist throughout either of argillaceous mica schists or of phyllite, changing towards the west into true mica schist with subordinate bands of chloritic schist or chloritic mica schist.[2] In most cases both the phyllite and mica schist, which are probably of Silurian age, but more especially the latter, are rich in interlaminations of quartz, which are sometimes less than one-fourth of an inch in thickness,

[1] *Reports of Geological Explorations during* 1878-79, p. 49, Wellington, 1879.
[2] F. W. Hutton and G. H. F. Ulrich, "Report on the Geology and Gold Fields of Otago," p. 156, Dunedin, 1875.

but occasionally attain a width of three or more feet. These generally lenticular masses, which have no regularity or persistence either in strike or in dip, frequently contain gold, and there can be no doubt that the gold in the drifts of the province is in some measure due to their denudation and disintegration.

Some of the reefs are, however, true lodes, with well-defined walls having clay selvages, and crossing the country rock both in strike and dip. Others are composed of a mixture of quartz and mullock, and are known as "quartz mullock reefs"; these are usually so soft that they can be worked without the aid of gunpowder, and the quartz, which does not appear to form a large percentage of the mass, occurs only in the shape of coarse sand and small and slightly rounded fragments. Whether the quartz originally formed interlaminations in the mullock, or occurred in veins is uncertain, but Mr. Ulrich considers that a kind of banded structure which is observable on the line of dip is in favour of the latter hypothesis. The reefs of Arrow and Skipper's Creeks are true lodes, some of which are twenty feet in thickness, cutting through the country both in strike and dip, and showing more or less distinct walls with clay casings. In point of composition and structure they, however, approach far more nearly to mullock reefs than to quartz reefs; they in fact represent fissures partly filled with *débris* from the country rock, mixed with interlaminated quartz, of which there are veins and branches of varying dimensions. "Layer lodes" follow the strike and dip of the country rock, having throughout for their foot wall one and the same bed, while the hanging wall is generally irregular, and frequently traversed by veins and branches of quartz. On account of this mode of relation to the country rock they are subject to all its changes of strike and dip, and, when these are great, they are liable to frequent changes in thickness, and are regarded as being the least promising form of reef.

The so-called Peninsula Quartz Reefs at Portobello are not in reality quartz reefs at all, but merely impregnations of finely divided gold enclosed in siliceous segregations in trachytic rocks. This occurrence of gold in a trachytic matrix is however not without its alliances, since the greyish-white trachyte of Portobello bears a certain resemblance to the gold-bearing trachytic tufa of the Thames gold-field in the North Island; although in the latter locality the gold is found in distinct veins and bunches of genuine quartz, and does not occur disseminated through the mass of the rock as in the other case. The rock in which the "quartz reefs" of the Thames gold-field are found is a massive formation of tufa passing on the one hand into a compact trachyte, and on the other into a coarse brecciated rock, consisting of angular fragments embedded in a tufaceous cement. The age of this formation is somewhat uncertain, but at Tapu Creek it rests upon black slate, and at Coromandel it is overlain by brown coal, which is again overlain, unconformably, by a recent volcanic formation referred to the Eocene period. It is therefore probable that the tufas in which the auriferous reefs are found, belong to some part of the Cretaceous period.

From some cause, not yet ascertained, this tufaceous formation has become decomposed in a very irregular manner, and to great depths; the undecomposed rock forming hard ridges separated from one another by belts of softened material extending to many hundred feet below the sea level. In these latter bands alone productive quartz veins have been found, and, so far as is at present known, they either pinch out or become unremunerative on entering the undecomposed rock.[1] Some of the reefs in this gold-field have been worked to a depth of above 100 fathoms below sea level. The following table, from official sources, shows the weight and value of the gold exported from New Zealand from the beginning of 1857 to the end of the year 1882.

TABLE SHOWING THE WEIGHT AND VALUE OF GOLD, THE PRODUCE OF THE COLONY, EXPORTED FROM NEW ZEALAND DURING THE FOLLOWING YEARS.

Year.	Weight.	Value.	Year.	Weight.	Value.
	Oz.	£		Oz.	£
1857	10,436	40,442	1870	544,880	2,157,585
1858	13,533	52,443	1871	730,029	2,787,520
1859	7,336	28,427	1872	445,370	1,730,992
1860	4,538	17,585	1873	505,337	1,987,425
1861	194,234	752,657	1874	376,388	1,505,331
1862	410,862	1,591,389	1875	355,322	1,407,770
1863	628,450	2,431,723	1876	318,367	1,268,559
1864	480,171	1,857,847	1877	371,685	1,496,080
1865	574,574	2,226,474	1878	310,486	1,240,079
1866	735,376	2,844,517	1879	284,100	1,134,641
1867	686,753	2,700,275	1880	303,215	1,220,263
1868	637,474	2,504,326	1881	270,561	1,080.790
1869	614,281	2,362,995	1882	293,229	1,170,520
Totals				10,106,987	39,598,655

[1] *Reports of Geological Explorations during* 1878-79, p. 22, Wellington, 1879.

In the year 1881, the quartz crushed in New Zealand amounted to 65,712 tons, yielding 84,792 oz. of gold, or 1 oz. 5 dwt. 19 gr. per ton.

OTHER METALS.—Copper mining was for some years conducted on a somewhat extensive scale at Kawau and Great Barrier Islands, but although a considerable amount of copper ore was obtained the mines were not financially successful. A small quantity of copper ore has more recently been raised from a vein on D'Urville Island, but the workings are by no means extensive, and the yield of copper ore has hitherto been but small.

Silver ores and argentiferous lead ores are sometimes met with in the gold-bearing reefs of Coromandel and the Thames, but no distinct lode of either of these minerals has yet been discovered. Specimens of cassiterite have from time to time been found in the Thames gold-fields.

In the Westland District, South Island, eight miles from Greymouth, in the hills north of the Grey River, where there were formerly extensive sluice diggings, is a quartz reef which never until somewhat recently attracted much attention. In 1878, however, some blocks of stibnite found in the alluvium were discovered to contain a considerable proportion of gold. This lode, which is known as "Langdon's Reef," is about 600 feet above the river, and appears as a solid ledge of white quartz from three to eleven feet in thickness, encased in compact slate. The quartz of this lode contains traces of antimony, and specimens taken from portions of the vein traversed by blue strings of stibnite yielded gold at the rate of 84 oz. per ton. Following up the same creek, at an altitude of 400 feet above Langdon's Reef, the lode from which the auriferous stibnite was originally derived has been discovered. It has a total width of nine feet, and is divided into five distinct bands, three of which consist of a mixture of quartz and stibnite, one, two feet in width, mainly consists of compact stibnite, while the fifth is composed of about one foot eight inches of brecciated slate. Specimens from this lode forwarded to Dr. Hector for assay yielded gold 84 oz. and silver 36 oz. per ton, but the highest results obtained from specimens collected by Dr. Hector himself yielded gold at the rate of only 36 oz. per ton.[1] Cinnabar has been found in small quantities at Waipori, and iron ores in the form of limonite and black iron sands occur in various localities.

[1] *Reports of Geological Explorations*, 1878–79, p. 19.

NEW CALEDONIA.

It was at one time supposed that the mineral wealth of New Caledonia would rival that of Australia and New Zealand, but hitherto these hopes have been to a large extent disappointed. Gold and copper veins are known to traverse the primitive rocks of the north part of the island, and the serpentines contain ores of iron, chromium, &c. In the year 1863 a few grains of gold were found in the alluvium of the Houébiahomme Valley, and in 1870 workings upon an auriferous quartz vein were commenced, at a place afterwards named Fern Hill, by English miners, by whom the claim was taken up. By the month of September, 1873, a mill had been erected, and 1,200 tonnes of quartz had been crushed; this yielded 4,663 oz. of gold; but, by the end of the same year, a mass of pyrites from which they failed to extract any gold had been reached, and the mine was shortly afterwards abandoned. Since that period little or no attention appears to have been devoted to gold mining, although it would appear improbable that this should be the only instance of the occurrence of auriferous quartz in the island.[1]

The most important ores furnished by New Caledonia appear to be those of nickel, for, although we are without any authoritative data relative to their annual production, this industry possesses considerable technical interest, from being founded upon a new ore which is, at least in part, treated by a new process.

This mineral, which is a silicate of magnesium containing nickel, was discovered by M. Jules Garnier, and has received the name of garnierite.

The method of extracting nickel from the ordinary ores of that metal consists in concentrating it as a regulus or speiss, dissolving in acid, precipitating the nickel in the form of oxide, and reducing the precipitate with carbonaceous substances. As garnierite contains neither sulphur nor arsenic, it becomes necessary to add one of these substances to the ore in sufficient quantity to take up the nickel, and this method of treatment is, under certain circumstances, recommended by M. Garnier. As, however, the sulphur and arsenic thus added have to be again separated from the nickel, a new process has been invented.[2] This consists in

[1] Émile Heurteau, "Les Richesses Minérales de la Nouvelle-Calédonie," *Ann. des Mines*, vol. ix., 1876, p. 307.

[2] J. D. Hague, "Mining Industries," p. 191, Washington, 1880.

smelting the silicate of nickel with iron ores in a blast furnace, with a cold blast, and at a low pressure. Under these conditions, and with a properly constituted mixture, only a portion of the iron is reduced, while the remainder passes into the slags, unaccompanied by nickel, and adds to their fusibility. In this way is produced a carbide of the two metals known as ferro-nickel, from which the nickel may be separated by a humid process.

AFRICA.

THE precious metals do not appear to be very generally distributed throughout Africa, and, so far as is at present known, the mineral productions of that continent are neither abundant nor varied. Until, however, the discovery of gold in California and Australia, the gold-fields of the Kong Mountains in Guinea were considered to be among the most important. Of all metals, gold is, perhaps, the most generally distributed in Africa. The gold-fields of the Transvaal are numerous, but the yield hitherto obtained from them does not appear to have been sufficiently large to compensate for the difficulties of working and transport. Dr. Soetbeer estimates the amount of gold produced in the whole of Africa during the year 1875 at 96,450 oz. troy.

Copper is known to exist in large quantities in the mountains of some of the native kingdoms of Central South Africa, and one of the objects of Dr. Livingstone's last journey was to visit the celebrated copper district of Katongo, south-west of Lake Tanganyika. At the Cape of Good Hope there are some valuable copper mines, while at Bembi, near Ambriz, a thick malachite vein was formerly worked by the negroes, and afterwards leased to an English company by the Portuguese Government. Abyssinia is supposed to be rich in copper ores, and iron ores occur in many parts of Inter-tropical Africa. On the banks of the Senegal, and in various other districts, the natives smelt iron, the ore used being a rich ferruginous sandstone of modern formation. Morocco contains ores of various metals, and Algeria deserves special notice, as some of its mines are both extensively and systematically worked.

ALGERIA.

The most important ores of Algeria are those of iron, which occur in the form of magnetite, red and brown hæmatite and siderite. Argentiferous galena, copper ores containing lead and silver, ores of antimony and mercury, as well as calamine and blende, occur in this part of Africa. Manganese, nickel, cobalt, and arsenic are likewise occasionally found, but always in association with ores of other metals.

IRON.—In the department of Constantine, the Mokta-el-Haddid Company works the mines of Kharézas, Bou-Hamra, and Aïn-Morkha, the last of which is connected with the port of Bône by a railway about twenty miles in length. This mine, which is more commonly known by the name of Mokta-el-Haddid, is an irregularly stratified deposit, included in mica schist, which originally formed a cliff 400 feet in height, exposed upon a bend in the outcrop where the iron ore is unusually massive. This deposit has been extensively worked as an open quarry by a succession of terraces each sixteen feet in height, of which nineteen were required to reach the top of the ore ground. The bed dips at an angle of about 30°, and its greatest thickness, measured horizontally, is somewhat more than 100 feet; but it gradually becomes flatter and diminishes in size until it is worked underground, where its thickness does not exceed twenty-eight feet. A second bed, thirteen feet in thickness, between the schistose roof of the main deposit and an overlying bed of limestone, has been discovered by boring. The ore is generally a blueish or blackish mixture of very dense hæmatite and magnetite, containing from 58 to 66 per cent. of metallic iron; a portion of it is, however, soft and brownish-red in colour, and can be readily worked without the aid of gunpowder.

In the department of Alger, spathic iron ores, and hæmatites resulting from their decomposition and peroxidation, are found in veins enclosed in Cretaceous rocks. These are for the most part associated with ores of copper and lead, which are, sometimes, the prevailing minerals.

Another class of deposits, occasionally of considerable importance, occurs in the department of Oran. These consist of hæmatites, associated with limestones, probably of Liassic age, and the ores, which vary considerably in composition, are often manganiferous, and in most cases moderately hard. Masses of totally unchanged limestone are sometimes found included in these ore bodies, whose origin M. Pouyanne attributes to the action of mineral waters.[1] Another class of deposits occurs in strata of Miocene age, and is considered to have been derived from the waste of Jurassic ores. The most important mines are those of Camérata, Soumah, and Beni-saf; the latter of which is situated about sixty miles west of Oran, and yields a soft calcareous hæmatite not unlike that of Bilbao.

The mines of Aïn-Morkha, worked by the Mokta-el-Haddid Company, annually produce about 400,000 tonnes of iron ore, and from 1867 to 1877 yielded 3,176,500 tonnes of the value of thirty-five millions of francs, or about £1,400,000. The production of iron ores in Algeria during the year 1880 amounted to 614,000 tonnes.

OTHER METALS.[2]—In the department of Constantine, in 1876, the lead mines of Kef-Oum-Theboul, near La Calle, yielded 12,000 tonnes of galena, containing about 38 per cent. of lead and affording work lead yielding 36 oz. of silver per ton. In addition to argentiferous galena this mine produces both copper ore and blende, while the mines of Cape Cavallo in the same department yield argentiferous lead and copper ores.

In the department of Alger some explorations for blende and galena are being carried on, and in the department of Oran the mine of Gar-Rouban produces small quantities of argentiferous galena.

The copper mine of Aïn-Barbar in the department of Constantine, eleven miles north-west of Bône, is worked upon several veins producing oxides and sulphides of copper, yielding from 8 to 15 per cent. of that metal, together with copper pyrites and blende.

Various mines have from time to time been to some extent worked near Cape Tenès, in the department of Alger, and have yielded limited amounts of copper and lead ores, but at the present time none of them appear to be in active operation.

The once celebrated copper mine of Mouzaïa, in the same department, which at one time was supposed to contain almost fabulous riches, and was the subject of much wild speculation, yielded antimonial grey copper ores only. In this locality there

[1] "Note sur la Région ferrifère des Ouelhassa," *Ann. des Mines*, vol. ix. 1876, p. 90.

[2] L. Ville, "Situation de l'Industrie minière des départements d'Alger, d'Oran et de Constantine," Algiers, 1874.

are several veins composed of spathose iron ore and heavy spar, containing disseminated antimonial grey copper ore, and traversing a soft marly country rock. When first discovered, the surrounding marly rocks of Cretaceous age had been to such an extent acted upon and removed by rain and other meteoric influences, that the outcrops of the veins stood from 12 to 15 feet above the surface of the adjoining ground, and could be thus traced as distinct parallel walls over a very considerable distance.

This mine, the working of which has been undertaken successively by various companies, was finally abandoned in 1865, on account of the difficulties experienced in the metallurgical treatment of its ores.

The mines of Oued-Merdja are situated on the right bank of a stream of that name, near the point of its confluence with the Oued-Chiffa, about seven miles south-east of Blidah. The concession contains several nearly parallel veins containing copper pyrites, but of these one only, namely, that nearest the point of meeting of the two streams, has been to any extent explored. The veinstone associated with yellow copper ore is principally ankerite, a triple carbonate of calcium, magnesium, and iron. In the year 1866 a powerful steam pumping-engine was erected at this mine, as well as furnaces for the conversion of the poorer ores into regulus.

In the vicinity of Blidah, in the valley of the Oued-Kebir, is situated the mine bearing the latter name. This concession may almost be regarded as an extension of that of Oued-Merdja, and is traversed by nearly similar lodes, towards the development of which but little has hitherto been accomplished.

Zinc ores are raised in the department of Constantine at the mine of Hammam-Nbaïl, belonging to the Vieille Montagne Company, at that of Aïn-Arko, and at the lead and zinc mine of Oued Maziz in the department of Oran.

The antimony mines of El-Hamimat are situated at a distance of forty-three miles from Constantine, and consist of a vein containing oxide of antimony at Semsa, and an irregular deposit of stibnite at Djebel Hamimat. These mines, which on account of local disturbances remained for some time unworked, have been re-opened.

The only known deposits of cinnabar in Algeria occur in the department of Constantine in the districts of Guelma and Jemmapes; but the only mine actually at work is that of Ras-el-Ma, fifteen miles south-east of Philippeville.

The production of metalliferous minerals, other than ores of iron, during the year 1880 was as follows:—

PRODUCTION IN ALGERIA OF METALLIFEROUS MINERALS OTHER THAN IRON ORES DURING THE YEAR 1880.

Description of Ore.	Quantities.	Values.	
	Tonnes.	Francs.	£
Lead and Silver ore . .	4,066	512,655	20,506
Copper ore	9,574 [1]	714,309	28,572
Zinc ore	976	42,615	1,704
Antimony ore	567	226,800	9,072
Mercury ore	200	10,000	400
Totals	15,383	1,506,379	60,254

CAPE OF GOOD HOPE.

During the last thirty years large quantities of copper ore have been obtained from Namaqualand, Cape of Good Hope, where it appears to occur in somewhat irregular deposits, interstratified with gneiss. The following amounts of ore, containing on an average $29\frac{1}{2}$ per cent. of copper, have been obtained from these mines since they were first opened in 1853.[2]

		Tons.
Raised from 1852 to end of 1862 from Springbok, Specktakel and Ookiepe mines		18,999
Raised by the Cape Copper Co. from 1862 to end of 1882, 20 years.	Ookiepe	164,025
	Specktakel	14,765
	Trial Mines	1,057
	Total	198,846

All these deposits are enclosed in gneiss, of which they appear to follow the strike and dip. That of Ookiepe, which has been the most productive, has been worked for a length of 175 fathoms, and to a depth of 105 fathoms. It, together with the enclosing rocks, is crossed by a slide, by which it has suffered a throw of 40 fathoms. Wherever it has been cut through in depth a bed of quartzite has been found immediately beneath it.

The value of the copper ores produced in Namaqualand during the year 1882 amounted to £331,546.

[1] Minerais complexes, equivalent to the bluestone of Anglesea, are returned in this table as copper ores.
[2] Statement furnished by Mr. R. Taylor.

NORTH AMERICA.

THE UNITED STATES.

Mr. R. W. Raymond,[1] in a paper on the mining districts of the United States, recalls the fact that W. P. Blake, in a note to his *Catalogue of California Minerals*, first pointed out that the mining districts of the Pacific slope are arranged in parallel zones, following the prevailing direction of the mountain ranges. More recently Clarence King has summarised these phenomena nearly as follows: The Pacific coast ranges carry, on the west, quicksilver, tin, and chrome iron ores. The next belt is that of the Sierra Nevada, and of the Cascade Mountains of Oregon, which, upon their western slope, carry two distinct zones, a foot-hill chain of copper mines, and a middle line of gold deposits, which extend into Alaska. Lying to the east of this zone, along the eastern base of the Sierras, and stretching southward into Mexico, is a chain of silver mines which are frequently included in volcanic rocks. Through Central Mexico, Arizona, Central Nevada, and Middle Idaho there is another line of silver mines, which more often occur in the older rocks. Through New Mexico, Utah, and Western Montana lies another zone of argentiferous galena lodes, and again to the east the New Mexico, Colorado, Wyoming and Montana gold-belt forms a well-defined and continuous chain of deposits. Raymond agrees that this parallelism exists, although in a somewhat irregular way, and that it is chiefly referable, as Blake and King have shown, to the structural features of the country. East of the Rocky Mountains there is but one longitudinal range, namely, that of the Alleghanies, which is accompanied by a gold-bearing zone of irregular extent and value.

Gold and Silver.

The gold-fields of the United States of America may be divided into three distinct groups, namely:—the Pacific division, the division of the Rocky Mountains, and the Eastern division. As however the first two of these groups sometimes yield both gold and silver from the same deposits, it will be more convenient to

[1] *Trans. Amer. Inst. Mining Engineers*, vol. i. 1873, p. 33.

include the two precious metals under one heading than to treat of them separately.

PACIFIC DIVISION.—The Pacific division comprehends California, Nevada, Utah, Arizona, Idaho, Oregon, Washington, and Alaska, and, although by far the most productive of the gold regions of the United States, it is by no means the oldest of them, gold having been first discovered in large quantities in California only in the year 1848. This State still continues to yield the largest amount of gold of any of the States or Territories of the Pacific division, but its production of silver is comparatively small.

The principal gold-bearing belt of California[1] extends along the lower slopes of the Sierra Nevada for a distance of more than 700 miles, and varies in width from twenty to sixty miles. The central mass of the Sierra consists of granite, which is flanked by clay slates, mica schists, chloritic schists, talc schists, and hornblendic schists, sometimes associated with quartzites and limestones. The strike of the sedimentary rocks constituting the auriferous belt is nearly north and south, and the enclosed veins of gold-bearing quartz course in a direction nearly parallel to its longitudinal axis.

The first statement relative to the age of these rocks was made by J. D. Whitney in 1864, and it now appears to be a well-established fact that a large portion of the auriferous rocks of California consists of metamorphosed Triassic and Jurassic strata, while nothing older than Carboniferous has been found in the gold-bearing region. The only fossils older than Triassic which have been discovered to the west of the crest of the Sierra Nevada are those of the limestone belt, of which by far the most fossiliferous locality is at Bass's Ranch, in Shasta County. The fossils, which here occur in great abundance, are of undoubted Carboniferous age.

In the southern portion of the State there are several gold-fields of subordinate extent, many of which may be regarded as practically exhausted, and which are now chiefly interesting as having furnished the earliest evidence of the existence of gold in California. Some of these southern placers are said to have been known to the Spanish missionaries long previous to the date

[1] J. D. Whitney, "The Auriferous Gravels of the Sierra Nevada of California," *Memoirs of the Museum of Comparative Zoology at Harvard College*, vol. vi., Cambridge, 1880. "Geological Survey of California," vol. i. 1865, p. 327. R. Silliman, "Report on the Deep Placers of the South and Middle Yuba," San Francisco, 1864. Clarence King, "Production of the Precious Metals," *Report of the Secretary of the Interior*, vol. iii. p. 335, Washington, 1882.

generally assigned to the first discovery of gold, but they, for prudential reasons, prevented as far as possible the spread of rumours respecting the existence of gold in the vicinity of their mission lands.

The original source of the gold of California is undoubtedly the veins of gold-bearing quartz which occur abundantly in the slates and other metamorphic rocks of the western slope of the Sierra. Historically, however, these veins of auriferous quartz are secondary to the shallow and deep placer diggings, in the former of which the first gold found in the State was discovered, and which for some years furnished nearly the whole of the gold produced in the country. There can be but little doubt that the gold in the auriferous gravels was originally derived from the degradation of veins of gold-bearing quartz, and the distribution of the detritus thus produced by the mechanical agency of water. It has also been conclusively proved that the gold-bearing gravels of California belong to two distinct periods, both of which are comparatively modern; those of the later period being distinctly separated in time from those of the earlier, from the breaking-up and re-distribution of the materials of which the later gravels chiefly derive their origin.

The sources from which Californian gold has been derived are consequently the following:—

1st. The distribution of placer gold by the present river system, giving rise to shallow diggings.

2nd. The distribution of placer gold by an ancient river system in beds of sand, gravel, and pebbles, known as deep diggings.

3rd. Gold-bearing quartz veins enclosed in metamorphic rocks.

The attention of the first miners was exclusively directed to the shallow placers, in which the gold lay near the surface, and within the reach of those whose whole capital consisted of ordinary mining tools. Here their labour was often abundantly remunerated, while the skill necessary was comparatively limited. In proportion as these surface deposits became impoverished and gradually exhausted, appliances were, by degrees, introduced for sluicing and collecting gold, requiring the employment of an increased amount of skill and a somewhat larger capital. Finally, it was discovered that extensive auriferous deposits were to be found at levels far above the course of the present streams, and an entirely new method of working became necessary. In order to meet these new conditions the system now known as the hydraulic process was invented, and deep diggings were inaugurated.

The gravels and cements of the deep diggings of California so closely resemble the deep leads of Australia, both in composition and in geological age, as scarcely to require a detailed description. As, however, the conditions in the two countries are not absolutely identical, a short abstract of Professor B. Silliman's description of the deep placers on the Yuba River may not be without interest.

In this locality the auriferous gravels have frequently, where they have been exposed to denudation, a thickness of 120 feet, and of more than 250 feet where they have been protected by a volcanic capping. These immense deposits consist of rounded fragments of quartz, diorite, syenite, and of all the metamorphic rocks found above them in the Sierra. They often enclose iron pyrites, and are frequently so cemented together as to form a hard conglomerate. In some instances these auriferous deposits have been found in the immediate vicinity of gold-bearing quartz veins, and have therefore, in such cases, been formed *in situ*. They are often locally stratified, but there is usually no continuity in the bedding. Generally speaking the lower portions consist of larger boulders than the upper, but this does not exclude the appearance of large rounded masses of rock in the middle and upper members of the series.

When a fresh section of one of these deposits is exposed, such as may be seen in hydraulic claims in active operation, a marked difference will be observed between the colour of the upper and lower portions of the mass. This is chiefly caused by the oxidation of iron pyrites through the action of surface water, thus staining the gravels red or brown in undulating lines contrasting strongly with the blue colour of the unoxidized detritus. The blue coloured portions of these gravels are highly impregnated with iron pyrites, which forms one of the chief cementing materials by which they are held together. Isolated patches of fine sand, frequently exhibiting indications of false bedding, are often observed in the upper portions of the deposit, and in these are found large quantities of silicified fossil wood, which, although retaining its original structure, is frequently flattened by pressure and blackened to the colour of coal. Analyses of two specimens of this wood will be found on page 5. In some instances these auriferous gravels are covered by a volcanic capping in the form of basalt, and in such cases the fossil wood is almost always beautifully silicified. Gold is, to some extent, disseminated throughout the whole mass of these great gravel deposits, but is always in greatest abundance near the bottom, and especially in direct contact with the bed-rock, which is usually grooved and polished by glacial or aqueous agency.

After the removal of the superincumbent gravels by the hydraulic process, the grains and scales of gold remaining upon the bed-rock are sometimes brilliantly conspicuous. These are, in many cases, inlaid so firmly upon the hard granitic bed of the ancient river course as to resemble a gilt mosiac; and the whole surface of the rock has to be worked over by the pick in order to secure the gold entangled within its substance. In cases where the bed-rock consists of comparatively soft materials such as mica schist or clay slate, it is usually found advantageous to break it up to a depth of from eight to ten inches in order to liberate the enclosed gold.

The ridge of land which is embraced between the Middle and South forks of the Yuba River is from six to eight miles in width, and, to the limits of the auriferous gravel, extends altogether about thirty miles, thus forming an area of approximately two hundred

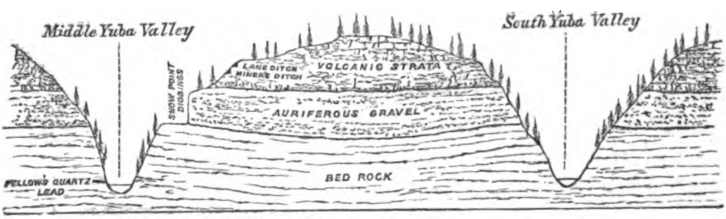

FIG. 86.—Section between the Middle and South Yuba Rivers.

square miles. The more elevated portions of this ground are covered by a heavy bed of volcanic ashes and breccia, as seen in Fig. 86, which represents a section upon a line drawn from the Fellows Quartz Lode, on the Middle Yuba, south-east, through Snow Point and Mount Zion to the South Yuba; once forming a continuous sheet over a region of considerable extent. This mass of volcanic ashes contains angular fragments of cellular lava, trachyte, basalt, porphyry, and of various other rocks foreign to the general geology of the country.

The extent of the gravels constituting the deep diggings of California is very large, and in some instances their richness has been remarkable. A French engineer who visited California many years since, states that, at Mokelumne Hill, 250 lbs. of gold had been extracted from a few centimetres of material lying immediately above the bed-rock, within an area of fifteen square feet.[1]

[1] P. Laur, "Du Gisement et de l'Exploitation de l'Or en Californie," *Ann. des Mines*, vol. iii. 1863, p. 412.

A remarkable deposit of auriferous gravel has been extensively worked under Table Mountain in Tuolumne county, the summit of which is occupied by a thick bed of, in some places, distinctly columnar basalt. This basaltic capping is, in the neighbourhood of Sonora, 150 feet in thickness, and near the entrance of the celebrated Buckeye Tunnel its width is about 1,700 feet. Beneath this lava is a heavy deposit of sedimentary material, consisting chiefly of a fine-grained sandstone interstratified with seams of clay and argillaceous shale. With these are associated beds of a strongly cohering conglomerate or cement, while at the bottom is found the ordinary pay gravel. In California, as in Australia, these lava-capped deposits are mined by means of shafts and levels.

The metamorphic rocks, which form a comparatively narrow zone, running from north to south along the western flank of the Sierra Nevada, contain numerous and important veins of auriferous quartz.[1] These are not by any means equally distributed thoughout the whole region of slates, but are chiefly concentrated in a belt having a width, from east to west, of some fifteen or twenty miles, and extending from north to south the whole length of the formation. These veins, for the most part, follow the general strike of the strata in which they are enclosed, although this parallelism is not always absolute. In many cases a vein, besides having a direction somewhat differing from that of the bedding of the enclosing rock, throws off strings and branches traversing the slate at considerable angles.

The gangue of the auriferous veins of California is invariably quartz, which is crystalline and semi-transparent, and contains a little alumina together with traces of potash. In many cases the quartz constituting an auriferous vein is ribboned in such a way as to present the appearance of a succession of layers parallel to its walls; one or more of these laminæ being often more productive than all the others. In some instances these parallel bands are separated from one another by thin layers of quartz differing either in colour or structure from that forming the seams themselves. In some cases, however, laminæ of the enclosing slates divide the vein into distinct bands, and in such instances the thickness of the interposed film of slate is sometimes not greater than that of the thinnest paper. Cavities or druses lined with crystals of quartz are occasionally, although rarely, found in the auriferous veins of California, but, generally

[1] J. A. Phillips, "Notes on the Chemical Geology of the Gold-fields of California," *Phil. Mag.*, vol. xxxvi. 1868, p. 231.

speaking, quartz crystals seldom occur in notable quantities in the more productive veins. When the structure of a vein is highly crystalline, and the quartz more than ordinarily transparent, it is considered an unfavourable indication with regard to its auriferous character. The quartz of the gold-bearing veins of the Pacific slope of the Sierra Nevada is, as a rule, comparatively free from the fluid cavities which are of such frequent occurrence in that of ordinary lodes.

The minerals usually associated with gold in the auriferous veins of California are iron pyrites, blende, and galena, with, less frequently, mispickel, magnetic pyrites, copper pyrites, and cinnabar. These sulphides invariably enclose gold, and veins in which some one or more of them does not occur in notable quantity are not often lastingly productive. Near the outcrops the iron pyrites and other sulphides become decomposed by the action of air and the percolation of surface waters; staining the quartz of a red or brown colour, and leaving the gold in a form favourable for amalgamation. In such cases moulds after cubical iron pyrites are found in the decomposed veinstone, and, although that mineral has been entirely removed, the cavities left by it contain finely divided gold, obviously liberated by the oxidation of the mineral. Beneath the line of the natural drainage of the country the sulphides remain undecomposed, and the extraction of gold becomes more difficult.

In addition to the gold thus enclosed in the various metallic sulphides, grains and small flakes of that metal are disseminated through the veinstone, and this is especially the case in the vicinity of certain dark coloured streaks generally almost parallel to the lines of apparent deposition of the quartz. This dark substance is, in some cases, roscoelite, a micaceous mineral containing above 28 per cent. of vanadic oxide. When gold is found lining a drusy cavity or is enclosed in the plastic selvage of a vein, it often occurs in well-formed crystals; but, when crystallization has taken place in a narrow fissure, the crystals are much flattened and often become plate-like in form.

The veinstone regarded by quartz miners as most "favourable for gold," is seamy, stained by oxide of iron resulting from the decomposition of iron pyrites, mottled, and somewhat resembling marble. In addition to quartz, hydrated silica, or semi-opal, and chalcedony have occasionally been observed in auriferous quartz veins, and in some instances the opaline silica is interfoliated between layers of normal quartz, and is conveyed with it to the stamping mill for treatment. A well-defined band of semi-opal of this kind was visible in the North Star Vein, at Grass Valley, when I visited that mine in 1865.

The walls of the auriferous quartz veins are generally smooth and well defined, and often afford evidence of a considerable amount of faulting. In case of a lead [1] being divided into bands by interfoliations of slate or otherwise, the planes of junction are sometimes marked by deep groovings, indicating that a grinding action has taken place between the adjoining surfaces.

One of the most remarkable gold veins in California is the Great Mother Lode, extending from Mount Ophir in Mariposa County to Mokelumne Hill in Calaveras County, a distance of over seventy miles. This lead, which frequently crops boldly out above the surface of the ground, and varies in thickness from 6 to 60 feet, may, in some places, be traced almost uninterruptedly for miles across the country, and often presents an outcrop resembling an immense white wall. Although not absolutely continuous or always remuneratively productive, this may be regarded as an axis with regard to the other veins of the auriferous region, which have generally a nearly similar direction, and are most frequently grouped at no very considerable distance on either side. As a general rule the quartz veins of California have not been found more subject to impoverishment in depth than are other metalliferous deposits, many of them having been worked below 1,500 feet without any diminution of their gold having been observed.

Nevada produces more gold than any other county in California, its yield during the year 1881 being estimated at $3,700,000.[2] In this county there are some important quartz mines, nearly all of which are situated in the immediate neighbourhood of the town of Grass Valley. Of these mines the Idaho is now the principal, and during the year above referred to crushed 27,945 tons [3] of quartz, which yielded 30,965 oz. of gold.

At the present time the richest quartz mines of California are those of the Bodie district, situated in Mono County.

The following description of this region is from a report by

[1] In California a quartz vein is called a "lead," and in Australia a "reef." In the gold regions of the latter country the term *lead* is applied to the deposits of the deep placers.

[2] In American statistics of production, the assay value of bullion is given in dollars; the value of an ounce troy of gold being $20·6718, while the value of an ounce troy of silver is $1·2929.

[3] The American ton weighs 2,000 lbs.

B. Silliman made in the year 1864.[1] Bodie Mountain, the point of chief interest in the mining district of the same name, is one of the highest inhabited points within the limits of the United States, its summit being 9,500 feet above the level of the sea. The general aspect of the country is desolate, the mountains are bleak and precipitous, and the cliffs broken into rugged steeps strewn with fragments of decomposing rock. Bodie Mountain is an isolated mass of trachytic porphyry, consisting of a lavender-coloured ground-mass enclosing crystals of a white felspar, and facts appear to point to the conclusion that the whole region, at a not very remote geological epoch, was the centre of great eruptive energy. In Mono Lake, twelve miles distant from Bodie, traces of these ancient fires still exist, as is evidenced by the escaping jets of hot vapour, and the numerous boiling fountains which occupy the islands in the centre of the lake. A close examination of the district leads to the conclusion that Bodie Mountain is an island of eruptive rock, having a length somewhat exceeding two miles with a width of about one mile, its crest being subdivided into three prominent points known respectively as Bodie Bluff, High Peak, and Silver Hill.

The whole surface, to the summit, is covered with *débris*, the porphyry in its decomposition having furnished an ochreous earth in which are seen abundant fragments of quartz, jasper, chalcedony, and other veinstones derived from the breaking up of the crests of the various lodes which intersect the mountain in a general course of N. 25° E. An exploration of the surface of the mountain resulted in the discovery of sixteen nearly parallel quartz veins, which are described with considerable detail, and the author proceeds to remark :—

"They are all, at surface, hard, compact, uncrystalline chalcedonic quartz, sterile of metal, and unpromising for mining explorations; at a pretty uniform depth of forty or fifty feet from the surface they gradually lose these characteristics, becoming softer as we descend, the quartz assuming more and more a fissile and friable character; the compact or chalcedonic portion, greatly diminished in bulk, forms now a lining upon one or again upon both sides of the vein, or, more rarely, a seam of varying width in the centre of the vein; patches or "horses" of the adjacent porphyry occasionally diminishing the vein, which immediately beyond assumes again the largest proportions.

[1] B. Silliman, "Report to the Empire Gold and Silver Mining Company, April, 1864.

"The metallic contents are found distributed, usually invisible to the eye, but indicated by dark coloured stains parallel to the surfaces of the quartz, and, when visible, rarely seen in particles larger than grains of mustard seed, and of a spherical or rounded form rather than in plates or scales.

"The observer accustomed to the character of auriferous quartz in other portions of the United States, or elsewhere, is struck also with the remarkable absence of the metallic sulphurets. Mispickel, so commonly the associate of gold elsewhere, seems here to be completely absent; even yellow iron pyrites and magnetic pyrites are rarely seen. Magnetic iron ore is pretty uniformly found, however, in minute particles, when samples of these ores are washed in the ordinary manner."

Professor Silliman observes that it is obvious from the foregoing statements that the Bodie district is one of the most valuable localities for the precious metals hitherto discovered in the United States. W. P. Blake, about the same period, remarks with regard to the Bodie veinstone that, instead of being a solid homogeneous mass, it is formed in layers or coats one over another like sheets of paper or paste-board, with irregular thin seams or openings between. "This structure, with other peculiarities, indicates that the veins were deposited gradually in the fissures by thermal springs, similar, perhaps, to those now existing at various points along the eastern base of the Sierra Nevada, as for example at Steamboat Springs, Washoe."

The most productive mine of the Bodie district is the Standard Consolidated, which employs about 150 miners. Its present depth is about 175 fathoms, and its production of gold and silver in 1881 slightly exceeded $2,000,000; during the year 1882 the total yield of bullion was $2,084,550. The Bodie Consolidated is taking from sixty-five to eighty tons of ore per week from the Fortuna Vein, and shipping above $7,000 in bullion weekly. The production of the Bodie Consolidated Mine during the year ending June 1st, 1882, was 132,040 oz. of bullion, value of gold $262,421·17; of silver $143,737·08; total $406,158·25.

The bullion shipments from Bodie district in 1881 amounted to $3,173,000, an increase of more than a million of dollars over those of 1878, the year of greatest excitement in the Bodie mines.

According to an official return the production of gold in California for the year ending May 31st, 1880, amounted to $17,150,941, or 829,676 oz. troy, of which $8,580,982, or 415,105 oz., were the production of hydraulic, placer, drift, and river mines, and the remainder obtained from the treatment of gold quartz. The Director of the United States Mint estimates the production of gold in California in 1881 at $18,200,000, and in 1882 it was probably something over $15,000,000.

Although California maintains its position as the great gold-producing State of the Union, and the deposits of auriferous gravel still continue to yield large quantities of the precious metal, their exhaustion, in view of the enormous hydraulic operations now carried on, may be looked for at no very distant period. Previous to the discovery of the Bodie district, the placer mines yielded about two-thirds of the gold production of the State, but the large output of the mines in that region, now amounting to above two and three-quarter millions of dollars annually, independent of a considerable production of silver, has placed the deep mines almost on a par with the placers as regards the total value of their returns. The amount of silver contributed by California is comparatively small, and is chiefly obtained in the adjoining counties of Mono and Inyo.

The production of the precious metals in the State of Nevada showed in the census year, ending 31st May, 1880, a considerable decline as compared with that of the preceding six years. This is however to be entirely accounted for by the falling off in the yield of the Comstock Lode, and is not due to any decline in the general mining prosperity of the State. The most remarkable metalliferous deposit in the State of Nevada is unquestionably the Comstock Lode, situated on the eastern side of Mount Davidson and partly underlying the towns of Virginia and Gold Hill. In addition to numerous papers scattered through the pages of various scientific publications, some very important memoirs of a more special character have been written upon the Comstock Lode. In 1865 Baron v. Richthofen made an examination of this district, the results of which were printed by the Sutro Tunnel Company, and in 1867 the same able geologist published a second paper, entitled "A Natural System of Volcanic Rocks," as a memoir of the California Academy, the classification proposed being avowedly, to a great extent, based on the geology of the Comstock region.

At the date of the publication of these papers microscopical petrography was still in embryo, and it is consequently not to be wondered at that subsequent investigations, aided by the use of the microscope, have led to somewhat modified petrological results; but so far as the structure and formation of the vein itself are concerned the views of v. Richthofen have been confirmed in a remarkable manner by the results of subsequent investigation.

In 1867 Mr. Clarence King, at that time in charge of the exploration of the 40th Parallel, made an examination of the lode down to the 800-foot level, and, although accepting v. Richthofen's propylite, he at the same time expresses a doubt whether eventually it might not be found identical with andesite. The quartzose rock which v. Richthofen had determined as a Pre-Tertiary quartz-porphyry, King regarded as quartz-propylite. In 1875 the rocks of this district were microscopically examined by Professor F. Zirkel, who confirmed the independence of propylite and quartz-propylite as lithological species, and regarded the quartzose rock as dacite; he also corrected the determination of the granular diorite, which had been called syenite, and added augite-andesite, rhyolite, and a variety of basalt to the list of rocks previously recognised. In 1877 Mr. J. A. Church examined the workings down to the 2,000-foot level. The memoir of this gentleman contains various original hypotheses, among which the two following are conspicuously prominent, namely: that the ores were deposited by substitution for propylite, and that the heat of the Comstock Lode is due to the kaolinizing action of surface waters on the felspars of the country rock. Finally, Mr. G. F. Becker, under the direction of the Hon. J. W. Powell, has prepared a monograph on the geology of the Comstock Lode. Of this report on the Comstock and Washoe districts a summary has already appeared.[1]

According to the United States Geological Survey[2] the Virginia Range has resulted from a Post-Jurassic disturbance, attended by the phenomena of folding and compression acting horizontally. It has also passed through an era of disturbances in Tertiary and Post-Tertiary times, during which the vertical component of the dislocating force was greatly in excess of the horizontal. This disturbance consequently resulted in a great amount of faulting throughout the whole region, but was not attended by extensive lateral compression or by folding. The era of Post-Jurassic disturbances was marked by the emergence of three massive rocks, namely, granite, diorite, and diabase. During the Tertiary and Post-Tertiary periods no less than eight different volcanic rocks were ejected; these have been described by American geologists as propylite, quartz-propylite, hornblende-andesite, dacite, augite-andesite, trachyte, rhyolite, and basalt. All of these rocks

[1] *Report of the U.S. Secretary of the Interior*, vol. iii. 1882, pp. 293-330.
[2] *U.S. Geological Survey, First Annual Report*, p. 39, 1880.

occur within a mile and a half of the Comstock Lode, and there is a point at the southern end from which a circle can be drawn with a radius of one and a-quarter miles, enclosing occurrences of the whole of them. Mr. Becker, after a careful study of a large number of thin sections under the microscope, has, however, arrived at the conclusion that the rocks which have been classed as propylite, in the Comstock district are merely decomposed forms of species previously known.[1] He enumerates the rocks occurring in this region as granite, metamorphic schists, slates, and limestones, eruptive diorite of three varieties, metamorphic diorite, quartz-porphyry, an older and a younger diabase, an older and a younger hornblende-andesite, augite-andesite, and basalt.

The Comstock Lode, during the middle portion of its course, occupies a line of contact between masses of diorite and diabase, as seen in the accompanying section, Fig. 87, reduced from Mr. Becker's coloured drawing, in which the dotted portions represent

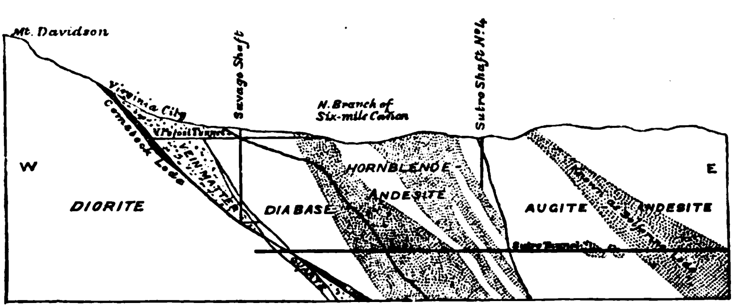

FIG. 87.—Section of the Comstock Lode.

solfataric decomposition. North of the Ophir Ravine it is walled on both sides by diabase; south of the Gold Hill Divide it leaves the diorite, and is carried southward, principally in diabase, but touches indistinctly the older metamorphic rocks upon its western side. This lode has been traced for a distance of 22,546 feet in a nearly due north and south direction, dips towards the east, and has a thickness usually varying from twenty to sixty feet. The vein fissure, which is also a line of fault, was probably formed in Post-Jurassic times, shortly after the final extrusion of diorite. The vein matter of the Comstock Lode consists of crushed and decomposed country rock, clay, and quartz. The country rock in and near the vein contains considerable quantities of

[1] *Report of the Secretary of the Interior*, vol. iii. p. xxiv. 1882.

pyrites and calcite, while gypsum is not of uncommon occurrence. The quartz is, for the most part, crushed into a finely granular mass closely resembling ordinary commercial salt. This quartz was once crystallized, and has evidently been crushed by the movement of the hanging wall upon the foot wall.

The Sutro Tunnel, starting from the Carson Valley, penetrates the eastern country rock for a distance of 20,000 feet, and strikes the lode near the middle of its productive portion 1,900 feet below its highest outcrop. The rocks passed through by the tunnel were hornblende-andesites alternating with augite-andesites, but for the last 1,000 feet before the lode is reached the rock is diabase, while beyond it the diorite of Mount Davidson is encountered. The mines upon the Comstock Lode were first opened in 1859, and on June 1st, 1880, the total length of the shafts and galleries in the different mines had already exceeded 150 miles. The number of men employed at that date was 2,770, while the aggregate horse-power of the machinery was 24,130, and the greatest depth reached exceeded 3,000 feet, or 500 fathoms.

The most remarkable phenomena in connection with the Comstock Lode is the intense heat which prevails in the lower levels. In the Yellow Jacket Shaft a large body of water was struck at a depth of 3,065 feet, of which the temperature was 170° Fahr., and which was impregnated with sulphuretted hydrogen. In the Forman Shaft there was a gradual increase of temperature amounting on an average to 1° for every 34·2 feet. The heat of the Comstock Lode has been generally ascribed to expiring volcanic agencies, but a few years since it was suggested by Mr. Church that it might probably arise from the kaolinization of felspars. To the latter theory objections have on more than one occasion been raised,[1] and the recent observations and experiments of Mr. Becker have yielded results by no means in favour of the kaolinization hypothesis.[2] Some particulars relative to the amount of heat carried off by the waters of the Comstock mines will be found at p. 71. With a view of testing the probabilities of Sandberger's theory of lateral secretion, the rocks of the Comstock district have been assayed with all possible precaution by Mr. J. S. Curtis. The constituents of the rocks found to contain the precious metals were separated by Thoulet's method, and the metals thus traced to their

[1] J. A. Phillips, *Quart. Jour. Geol. Soc.*, vol. xxxv. 1879, p. 390 ; *Nature*, vol. xxii. 1880, p. 337.

[2] G. F. Becker, "A Summary of the Geology of the Comstock Lode," Washington, 1882.

mineralogical sources. The results of this investigation furnished many interesting facts, among which may be mentioned the following, namely: that the diabase contains a notable amount of the precious metals, of which the larger proportion is contained in the augite; that the decomposed diabase contains about one-half as much of these metals as the comparatively fresh rock; that the relative quantities of gold and silver, both in the fresh and decomposed diabase, correspond fairly well with the known composition of the Comstock bullion; and that the total exposure of diabase is sufficient to account for far larger quantities of bullion than have been extracted from the mines.

In 1876 the yield of the Comstock, according to Mr. Del Mar's estimate, was:—gold $18,002,906, silver $20,570,078; total $38,572,984. During the census year the whole Comstock district, including the Virginia, Gold Hill, and Devil's Gate sub-districts; the outlying veins, such as the Occidental, &c., and the yield of tailings worked at various points throughout the entire tract known as the Washoe Country, was:—gold $3,109,156, silver $3,813,174; total $6,922,330; showing a decline of $31,650,654 or 82·06 per cent. since 1876. From the time the first mines were opened in 1859 to 1st June 1880, the Comstock Lode had produced about $315,000,000 worth of bullion, of which $175,000,000 was silver and the remainder gold. Out of the above total yield about $115,871,000 had been paid in dividends.

Some of the most productive silver mines in the State of Nevada are situated in the Eureka and Ely districts. The White Pine region, which, after the discovery of the mines in 1868, was the scene of great excitement, now yields comparatively small returns. The Eureka district consists mainly of metamorphic limestones exhibiting traces of stratification, lying on quartzite and overlain by shale. In these limestones, which are partly of Cambrian and partly of Silurian age, are distributed irregular chimneys and pockets of ore consisting of galena with sulphate and carbonate of lead. This ore usually contains about 25 per cent. of lead, and 50 oz. of silver per ton. The Richmond and Eureka Consolidated, both situated in the southern portion of the district, are the most productive mines.

Throughout this district a great ore-channel extends along the eastern base of Prospect Mountain for a distance of twelve miles. This appears to be a contact deposit in a formation of limestone, quartzite, shale, &c., and from the various mines scattered along the main deposit and its various branches above fifty millions of dollars have been extracted. The Richmond, which is the property of a London company, is reputed to be one of the best paying mines in America, and is now down 1,230 feet below the surface. The Richmond furnaces have the reputation of being the largest producers in the world, and the accumulation of lead in that company's premises in July 1881 was about 50,000 tons of market metal, there being an acre of ground outside the refinery piled solidly five feet high with pigs of lead. This mine during the first nine years of its existence produced $61,000,000 of bullion. Of the total yield of the ore 33 per cent. is gold and 66 per cent. silver, with a production of one ton of lead to five tons of ore smelted; 500 men are employed at the mine and furnaces, 500 more furnishing fuel, &c.

The Eureka Consolidated has had from the time it was first opened, a dozen years ago, a prosperous existence. The output for the quarter ending September 30th, 1881, was $305,074, and, according to published statements, bullion to the value of $1,396,618 was shipped during the year.[1]

The yield of the placer mines of Nevada is comparatively insignificant, as no important gravel deposits provided with a suitable water-supply are known. The total production of bullion in this State during the census year was: gold $4,888,247, silver $12,430,666.

The bullion production of Utah, if not remarkable for its amount, is at least very regular in quantity, and has not materially varied for many years. The proportion of gold annually obtained is small as compared with that of silver, and the only placer gold produced, amounting in the census year to about $20,000, was from West Mountain district in Salt Lake County. Above one-fifth of the total production of bullion in this Territory appears during the census year to have been supplied by the mines of the Ontario Silver Mining Co., which are situated near Park City, Utah, thirty-two miles east of Salt Lake, and at an elevation of about 8,000 feet above the sea. The principal mining claims belonging to this company are the Last Chance, Ontario, and Switzerland, extending on a line on the direction of the lode, and each 1,500 feet in length by 200 feet in width. The vein fills a strong well-defined fissure having a course nearly east and west, with a northerly dip varying from vertical to 70°. The vein fissure traverses a belt of quartzite, cutting through the layers of the formation uncon-

[1] "Report of the Director of the Mint upon the Production of Precious Metals in the U.S.," Washington, 1882, p. 129.

formably both on the dip and the strike. On the north, or hanging wall of the vein, is a dyke of grey porphyry 100 feet in width, intersecting the bedding of the quartzite with a general course nearly parallel to the lode. On the east this porphyry approaches closely to the vein and in some places even forms its wall. Towards the west it diverges and is separated from the vein by a variable thickness of quartzite.

The lode has been explored on its course by underground workings for a distance of nearly 3,000 feet; the deepest point at which it has been cut being at the seventh level or over 700 feet below the outcrop. The fissure varies in width from two to twenty feet, the usual width being from four to five feet, and throughout this large extent no faults or dislocations occur, the continuity being unbroken. The filling mainly consists of material derived from the walls, being a mixture of finely ground quartzite and clay, resulting from the decomposition of the encasing porphyry. The ore has been deposited in the fissure in a continuous sheet, extending from the surface as far downwards as the explorations have penetrated, and forming a well-defined shoot of ore. At the surface this shoot had a length of only about 500 feet, the fissure, although continuing beyond the ore body to the east and west, being filled with material derived from the walls and containing but small quantities of mineral. As this shoot was followed in depth it increased in length, until at the sixth level it attained a length of 1,500 feet. Not only has this increased in length as it has been explored in depth, but there has also been a gradual increase in the width of the ore, which in the upper levels averaged only from one foot to one and a half foot, while in the fifth and sixth levels it is at least two and a half feet wide, and for considerable distances occupies the whole breadth of the fissure. With this increase in the dimensions of the shoot, the ore has become richer as greater depth has been attained. The first ore worked yielded an average of from $70 to $80 per ton, while that extracted from below the fifth level mills from $125 to $145 per ton, and the vein, where cut at the depth of 700 feet, samples still higher.

Below a depth of 400 feet the ore is undecomposed, consisting essentially of argentiferous blende, associated with small quantities of grey copper ore rich in silver, a little galena, and iron pyrites. Nearer the surface the ore has been much changed by oxidation, zinc having been removed, and the silver occurring mostly as chloride with some native silver and oxidized copper and lead minerals. The gangue forms about 35 per cent. of the ore as it goes to the mills, and is composed of clay and disintegrated quartzite. The ore is sometimes massive, although the vein frequently exhibits a banded structure with seams parallel to the walls, yet showing no evidences that the process of formation was interrupted. The ore is soft, friable, easily mined, readily detached from the walls, and is separated from the gangue without difficulty. The mine is very wet, especially in the western ground, necessitating the use of powerful pumping machinery.

The Ontario Mine was discovered June 19th, 1872, and the amount of ore extracted from that date to January 1st, 1877, was 13,604 tons, yielding $1,056,713 gross bullion. From January 1st, 1877, to April 1st, 1881, the quantity of ore mined and milled was 62,601 tons, yielding $6,950,788, a total production of 76,205 tons and a gross bullion value of $8,007,501, being at the rate of $105·08 per ton.[1] The total production of the precious metals in Utah during the census year ending May 31st, 1880, was $5,034,645. During that period the production amounted to:—gold $291,555, silver $4,743,090.

A considerable impulse has been given to the mining industries of Arizona by discoveries recently made in the Tombstone district, in Pima County, but the bullion production of that area had only begun to come forward during the period covered by the late census.[2]

The mining district and town of Tombstone are situated in Cachise County, Arizona Territory, at the north-west end of the Mule Pass range of mountains, on the right bank of the San Pedro River, from which the town is nine miles distant. It is also twenty-four miles south of Benson Station on the Southern Pacific Railroad of Arizona, and about forty miles north of the Mexican line. Its altitude above the sea is approximately 4,600 feet. The Dragoon Mountains rise to the north-east, and the Huachuca Range lies on the south-west. The country is without timber, and the surface where the mines are opened is in general gently rolling and accessible to waggons by natural roads. The first mining grants were made in the year 1878, and there are now probably over one thousand claims taken up in the district and upwards of 2,500 inhabitants. The output of the precious metals, gold and silver, up

[1] W. Ashburner and W. P. Jenney, "Report on the Ontario Silver Mining Company's property," San Francisco, 1881.

[2] William P. Blake, F.G.S., "The Geology and Veins of Tombstone, Arizona," *Trans. Amer. Inst. Mining Engineers*, vol. x. 1882, p. 334.

to January 1st, 1882, amounted to $7,359,200, and over $3,000,000 had been disbursed in dividends.

In going from Benson to the mines the traveller rises from the Post-Pliocene deposits along the San Pedro to a granitic plateau. The rock is grey and highly crystalline, is apparently eruptive, and weathers into gigantic rounded blocks lying one upon another, as if piled there by some enormous force, and extends to within a mile or two of Tombstone, where stratified formations occur overlying the granite. These stratified beds consist of quartzites, limestones and slates, with frequent repetitions in an ascending series several thousand feet in thickness; but all conformable, and dipping, generally at a low angle, toward the east. The fossils which have been found in the middle and upper beds show them to be Palæozoic and probably of Lower Carboniferous age, while the lower strata are probably older.

In addition to the stratified formations there are intrusive porphyritic dykes cutting indiscriminately through the strata nearly at right angles, and trending, approximately, north and south. This is the direction of the general faulting of the country, and also of the mineral veins. In the central portion of the district erosion has exposed the outcropping edges of many strata of limestones, shales and quartzites. Both the shale and quartzite beds are very fine-grained and compact in texture, with scarcely any signs of granular structure. The latter is flint-like and hard, and is more exactly described as a novaculite or honestone; passing in places insensibly into siliceous limestone. An abundance of iron pyrites in fine crystalline grains is disseminated through the layers of this rock, which derives special importance from the fact that the mines on the Tough Nut and Good Enough claims find it below the chief ore-bearing limestone. The beds above it consist of dark, black, or blue limestones, and of thick beds of dark argillaceous shale, alternating with black siliceous shales for nearly half a mile to the eastward. The black limestones above the novaculite are the chief repositories of the bedded masses of rich silver ore.

The whole series of beds in this central part of the district is thrown into folds, being regularly plicated in a series of wave-like flexures which may be traced, although with some difficulty, upon the surface, but are best seen in the cross-cuts of the mines and along the drifts. In the open cut upon the Tough Nut there is a good exposure of some of the beds at the crest of an anticlinal fold, presenting an appearance, in section along a north-east and south-west cut, as shown in Fig. 88, in which *a* is novaculite, under the limestone, *b* limestone bending over the novaculite, and *c* shales over the limestone.

This section is along the upper level known as the adit, and is directly below the place on the surface where ore was found cropping out mixed with soil and vein-stuff. At another place there is a series of plications, at about the angles shown, with rich ore lying in the folds. These folds are not large, covering a few hundred feet in extent only, but are beautifully regular and well defined; in the series of strata to the eastward the dip becomes more regular, coarse-grained quartzites, in thicker beds, taking the place of finer-grained deposits. All of the formations named have not only been uplifted as described, but have been much broken and faulted either at the time of uplifting or subsequently.

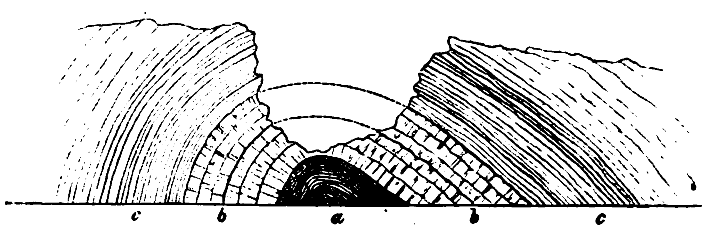

FIG. 88.—Anticlinal, Tough Nut claim.

The chief ore-bearing vein of the district traverses the Grand Central and the Contention claims. These were laid out in a north and south direction upon the somewhat obscure outcrop of a dyke of dioritic porphyry carrying ore in, through, and alongside it. The outcrop was not well-defined, consisting of porphyry and of a confused mixture of porphyry, chert, and quartz, with masses of porous quartzite alongside, none of the rocks rising high above the soil. There was, however, a considerable discoloration by oxide of iron, and a small amount of digging revealed good ore near the surface. This dyke varies in width from a few feet to seventy feet, and dips to the westward at an angle of from 55° to 65°. It cuts indiscriminately through shales, quartzites, and limestones, and is evidently of igneous origin. Its contact, however, with the abutting edges of the disrupted beds is not always marked by any material change in their appearance or composition, although in places there is obscure metamorphism, and some slight modification of structure. The dyke itself has a distinct vertical lamination, and is more or less penetrated by thin veins of quartz. In some portions it is highly crystalline, while in others it consists, chiefly, of a felspathic base in which the felspar crystals are obscure. It finally passes into a felsite, which, in the decomposed portions of the dyke and when slaty in structure, might be mistaken for altered shale or quartzite. Large portions of the dyke are so penetrated by quartz as to consist largely of that mineral, although close examination shows the presence of felspar.

There is also a considerable amount of mineralization of the dyke by iron pyrites disseminated irregularly in cubical crystals, most of which have dissolved out and left cavities only to indicate their former presence, giving rise in some places to a spongy mass of either porphyry or quartz. Although the mines have been worked to a depth of 600 feet and there are some twelve to fifteen miles of drifts, levels, and winzes in the Contention and adjoining mines, the undecomposed ores below the water-level have not been reached, and all the minerals above that point are in the decomposed and oxidized condition common to surface ores. A large portion of them is charged with red oxide of iron to such an extent that the clothing of the miners becomes saturated with the rouge-like powder, and the tailings at the mills are blood-red in colour.

There has been an extensive decomposition of the porphyry along the upper 300 feet of the dyke, resulting in the formation of quantities of kaolin, sometimes perfectly white and pure, but generally more or less stained by red oxide of iron. This kaolinization extends in places to the adjoining shales, and there are some white, clay-like interstratified beds, which may, on further examination, be found to be altered felsitic offshoots from the dyke. The only metalliferous contents, with the exception of the pyrites and some galena and lead carbonate, are gold and silver in a partially free state, part of the gold, if not all of it, being free; the silver occurring chiefly as chloride, with probably some iodide. The average value of gold and silver in the ores worked in 1880 was about $70 per ton. The gold represents from 20 to 25 per cent. of the value of the product, the remainder being silver. A very interesting fact is the occurrence of metallic gold, together with chloride of silver, disseminated in the midst of the porphyritic rock, at a distance of many feet from the portions of the porphyry carrying quartz in veins. This gold is found chiefly in a portion of the rock containing finely-disseminated hornblende. In decomposing, this porphyry becomes steatitic, and in places appears to be changing to serpentine. The gold is found in thin sub-crystalline flakes and scales, chiefly in and along thin seams and cracks in the mass of the rock, as if it had been infiltrated and deposited from solution.

Free gold is also found in quartz in the usual manner of association; but even in such specimens the crystalline felspar of the dyke is also found.

The whole of the dyke, together with the adjoining strata, has been subjected to extensive movements and displacements, shown not only by breaks of continuity, but by brecciated cross-courses and by seams traversing both the igneous and stratified formations. This disruption of the dyke, with its attendant fracturing and brecciation of the country rock, accompanied by the movement of the dyke upon itself, and the formation of heavy clay seams, has provided suitable places for the accumulation of ore, which is generally found in the softer and more broken portions of the dyke. The only place upon the lode where water has been reached is upon the Sulphuret claim. At this point the lode intersects limestone, and there is a bedded layer of ore following the stratification and connected with the dyke; this ore is chiefly galena and iron pyrites. Bedded ore deposits are associated with bedded dykes, and with vertical fissures nearly parallel with the Contention Lode. One of the longest and best defined is the West-side Lode, which may be traced for about two miles, until it passes into the underlying granite.

A line of fissure cuts across the anticlinal line of the formations at the open cut on the Tough Nut, and crosses the whole breadth of the Good Enough into the claim beyond. This has been followed on ore from the open cut, and is connected with the chief lateral bedded deposits. A lode has also been followed in the same general direction from the claim called the Defence across the Tough Nut into the Good Enough. This lode is marked by heavy outcrops of quartz, and by flinty boulders lying above the limestone on the surface.

The bedded offshoots from the vein, which are often of considerable lateral extent, following the planes of stratification on either side, may be due to the decomposition of nodular masses, but they are generally deposited in the limestone as if by replacement. They may be regarded as filling irregular cavernous spaces eroded in the strata by metalliferous solutions, and are without any regular boundaries. The bedded masses do not exhibit a symmetrical arrangement of the ore, except such as may be referred to stratification or deposition by gravity. It is to be observed that the bedded masses of ore occupy the limestone rather than the siliceous or argillaceous strata, as might be expected from the greater solubility of limestone. In extent the bedded masses have been much larger than the ore bodies of the vertical fissures, and it may be said that the larger portion of the production has been from beds or flats. They extend irregularly between two fissures, for a distance of about 400 feet measured diagonally along the dip. It is noteworthy that they follow the stratification for some distance and then suddenly break across it vertically, following a crack or break in the bedding, and then again expand horizontally for some distance to another crack, when they drop down by a series of steps from one layer to another between the limestones. The ores found in these bedded deposits in limestone are much more plumbiferous than is the ore of the felspathic dyke. Galena, blende, and iron pyrites are abundant in masses, which, within the reach of oxidizing agencies, are largely converted into oxides and carbonates.

The Castle Dome district lies in the foot-hills, and on the western slope of a range of mountains, in Arizona, eighteen miles east of Castle Dome Landing, on the Colorado River. The district, as already traced, is two miles in width and seven in length, following the trend of the mountains. The lodes in this district were re-discovered in the year 1863, but it is evident that they had been opened and worked, to a shallow depth, at a comparatively remote period, probably by some of the Spanish priests who first made their way from Mexico into Arizona. The ore, which occurs in true veins, is a dense brilliant galena, carrying about 30 oz. of silver per ton. The rocks of this region are compact fine-grained mica schists and clay slates, standing nearly on edge, and traversed by numerous porphyritic dykes, which apparently bear some close relation to the mineralization of the veins. The veins have a general north-west and south-east course, their outcrops being made chiefly evident by fragmentary crystals of rose-coloured fluor spar, which constitutes the chief veinstone accompanying the galena, and which forms an excellent flux for the ore. This is the only known instance of the general occurrence of fluor spar in lead-bearing veins in the United States. Calcite and gypsum are also often present, and in some of the veins quartz constitutes an important portion of the gangue, being either arranged as combs parallel to the walls, or forming sheets in the middle of the veins.

During the first six months of the year 1879 the shipments to San Francisco, where the works of the company are situated, amounted to 438½ tons of ore, yielding $21,367, or an average of $48 per ton of 2,000 lbs. The average percentage of lead was 69, and the contents of silver 26 oz. per ton. The value of the lead per ton was $25·61, and the value of the silver at 90 cents per oz. $23·89 per ton of ore; making a total of $49·50 per ton of ore.[1]

The total production of Arizona during the census year was estimated at $211,966 for gold and $2,325,826 for silver, and consequently the yield of the latter is much in excess of that of gold. Mr. King, however, states that from not being in some cases furnished with the necessary returns, the above estimate may possibly be wrong to the extent of some 20 per cent.

The gold production of Idaho during the census year amounted to $1,479,655, of which 59·42 per cent. was the yield of placers, and 40·58 per cent. the result of deep mining; the production of silver for the same year amounted to only $464,550. The principal mining areas are those of Owyhee, the New River country, and the Yankee Fork region.

Oregon is one of the oldest of the western mining States, the finding of gold within its boundaries having closely followed the discovery of that metal in California. Its yield was never large in comparison with that of the neighbouring State, but, although the mines have now become secondary to its agricultural resources, they still afford remunerative employment to many of its inhabitants. The quartz veins of the portion of the State which adjoins Idaho continue to yield the greater portion of the total deep-mine production of the country. The prevailing type of the ore is an easily worked auriferous quartz, although rebellious gold ores, requiring special treatment, are found in some localities, and a small amount of silver is produced in Grant County. This county also takes the lead in placer mining, while Baker, Jackson, and Josephine Counties also furnish a considerable amount of alluvial gold. The production of the precious metals in Oregon during the year ending May 31st, 1880, was :—gold $1,097,700, silver $27,793.

Of the comparatively small production of the deep mines of Washington Territory, by far the larger portion comes from the Peshastin district, in Yakima County, where quartz mining is carried on upon a limited scale. The Upper Columbia placers furnish above one-half of the alluvial gold annually obtained in the Territory. The yield of the precious metals during the year 1880 amounted, according to official returns, to :—gold $135,800, silver $1,019.

The vast region of Alaska, occupying an area of half a million

[1] W. P. Blake, "Report to Castle Dome Mining and Smelting Company," July, 1880.

square miles, remains for the most part still unexplored, while its exceptionally severe climate, and its remoteness from facilities of communication, must always remain obstacles to the development of its mines. Its gold is derived exclusively from placers, among which those of the Takou district are the most productive. According to official returns the total production of Alaska during the census year was:—gold $5,951, silver $51.

The total production of the Pacific division of the United States during the same year amounted to:—gold, $25,261,828, silver $21,143,881.

DIVISION OF THE ROCKY MOUNTAINS.—The division of the Rocky Mountains comprehends Colorado, Dakota, Montana, New Mexico, and Wyoming. This division yields 23·60 per cent. of the gold and 48·45 per cent. of the silver annually produced in the United States; in addition to which, a large proportion of the lead produced in the country is obtained from the mines of this region.

From an average annual production of between three and four millions of dollars, Colorado has suddenly risen to the first rank among the States and Territories as a producer of mixed bullion, of which the larger proportion is silver. As a gold-producing State it occupies the fourth place. The most important mining area in the State of Colorado is that in the vicinity of Leadville, a town situated in Lake County, on the western flank of the Mosquito or Park range of mountains, and on the eastern slope of the valley of the Arkansas, at a mean average elevation of 10,150 feet above the level of the sea. The Rocky Mountain Chain is here composed of three more or less parallel ranges; the Colorado or Front Range, the Mosquito or Park Range, and the Sawatch Range. The Arkansas Valley is a meridional depression about sixty miles in length, by sixteen in width, bordered by the sharp peaks of the Mosquito Range on the east, and by the equally high but broader mountain mass of the Sawatch Range on the west. At a distance of about twenty miles from its head the foot-hills of the bordering ranges close together, confining the present bed of the steam within a narrow rocky cañon, a few miles above the town of Granite.

On the upper edge of a gently-sloping terrace, between Big Evans and California Gulches, and at the base of Carbonate Hill, the extremity of a western spur of the Mosquito Range, is situated the city of Leadville. Gold was first discovered in 1859 on Tarryall Creek, at the head of the South Park, and early in the spring of 1860 two parties of prospectors stumbled almost simultaneously upon rich diggings in California Gulch, near the present site of Leadville. Large quantities of alluvial gold were obtained from this gulch, and a town was built along its banks, known as Oro City; the richer placers, however, became rapidly exhausted, and in the course of three or four years the population of the town of Oro had become reduced from thousands to hundreds. The miners of that date, who had acquired their experience in the gold-fields of California, knew little or nothing about the ores of silver, but prospecting for gold was, to some extent, carried on upon the outcrops from which the gold of the placer diggings had been derived. These operations resulted in the discovery of several gold mines which, for a time, brought back a gleam of renewed prosperity to the dwindling camp at Oro, but of whose yield no data are available. Few however, if any, suspected the value of the so-called "heavy rock," fragments of iron-stained carbonate of lead, which, being too heavy to be carried off by the force of running water, obstructed the sluices and required to be removed by hand.

The practical discovery of the argentiferous ores of Leadville was however made in 1875, and the first small lot was shipped to Saint Louis in 1878. Active prospecting over the whole region commenced in the spring of 1877, and the development of rich and productive mines from that time advanced with astonishing rapidity.

The most ancient rocks of the Leadville district are of Archæan age, consisting of granite and gneiss, above which follow successively Cambrian quartzites, Silurian white limestones, Carboniferous blue limestones and grits, and finally Quarternary deposits consisting of lake beds and post-glacial drifts. The igneous rocks of the district comprehend different varieties of porphyry, and the strata are traversed by numerous faults, which in some places represent considerable displacement. Throughout this region the stratum of dark blue, often nearly black limestone, at the base of the Carboniferous formation, is the most important ore-bearing rock. There are however other horizons in which ore is sometimes found, although in general in masses far inferior in quality and extent to those occurring at the contact of this limestone with the porphyry, which almost everywhere overlies it. The ore is principally argentiferous galena, with its products of alteration, cerussite and chloride of silver; while, as accessory minerals, anglesite, pyromorphite, minium, blende, and calamine are sometimes met with. Native sulphur has occasionally been found as a result of the decomposition of galena, as well as metallic silver, produced by the reduction of the chloride of that metal.

Mr. S. F. Emmons, of the United States Geological Survey, was for some time engaged in a study of the structural and mining geology of the district about Leadville, and material was gathered for an exhaustive monographic report on the geology and mining industry of the locality. In an abstract of this report, published in 1882, Mr. Emmons[1] remarks that, although his conclusions cannot claim the merit of great scientific originality, since similar opinions have already been put forth by investigators in other fields, they have been arrived at purely from an impartial study of the peculiar conditions of the district, without any pre-conceived theory which might tend, unconsciously, to bias the opinions of the observer. The most important facts observed and conclusions arrived at bearing upon the formation of these metalliferous deposits are:—

1st. "The occurrence, on an enormous scale, of intrusive bodies of eruptive rock of Secondary or Mesozoic age, and of exceptionally crystalline structure, which are so regularly interstratified as to form an integral part of the sedimentary series; and yet which never reach the surface, but were spread out and consolidated before the great dynamic movement or mountain-building period at the close of the Cretaceous.

2nd. "That the original ore deposition took place after the intrusion of the eruptive rocks, and before the folding and faulting occasioned by the great dynamic movement.

3rd. "The minerals contained in the principal ore deposits of the region were derived from circulating waters, which in their passage through the various bodies of eruptive rocks took up certain metals in solution; and, concentrating along bedding-planes by a metamorphic or pseudomorphic action of replacement, deposited these metals as sulphides along the contact or upper surface, and to greater or less depth below that surface, of beds generally of limstone or dolomite, but sometimes also of siliceous rocks.

4th. "That in the region immediately about Leadville the principal deposition of silver-bearing minerals took place at the horizon of the lowest member of the Carboniferous group, the Blue limestone formation, commencing at its contact with the

[1] "Abstract of Report on Geology and Mining Industry of Leadville," *Annual Report of the Secretary of the Interior*, vol. iii. 1882, p. 203.

overlying White porphyry. But that, while this particular formation has been peculiarly susceptible to the action of ore currents in this region, it is not admissible to assume, as some have done, that in general the beds of any one geological epoch are more favourable than those of any other to the formation of this important type of silver-bearing deposits; since, although they are generally found in greatest abundance in calcareous beds of Palæozoic age, the horizon of such beds is by no means identical in the various mining districts in which they have been thus far developed.

5th. "That in this, as in many other mining districts, dykes of eruptive rock, cutting the ore-bearing formation transversely, seem to favour the concentration of rich ore bodies or bonanzas in their vicinity.

6th. "That on fault planes, on the other hand, no considerable ore bodies have been deposited, as might have been assumed, *a priori*, from the fact that their origin is later than that of the original ore deposits."

On the other hand, Mr. J. Alden Smith, the State Geologist of Colorado, says in his recent report on the mineral resources of Colorado:[1]—"I am impelled to reiterate the opinions heretofore expressed, that the ore deposits of this district came from below through fissures originating in the granitic rocks, and, extending upward, penetrated the limestones and quartzites to the contact with the overlying porphyry; that these fissures lead to many bedded veins in the limestone or quartzite, and to contact veins of more or less value between the formations last mentioned, and between those and the granitic formation; and that these fissures and deposits will be extensively and profitably worked for centuries after the contact deposits now operated on are exhausted."

The *Leadville Herald* states that the metallic production of Leadville for the year 1881 was $13,170,576. The statement of the year's yield made up by the *Leadville Democrat*, shows a less production. It states that, from ore supplied by 131 mines, 7,174,234 oz. of silver, and 11,135 oz. of gold were obtained, together with 37,204 tons of lead, representing a value of $13,100,761. This, however, omits the gold production of the gulch mines, reported at $69,000, which, added to the total, brings the product to

[1] "Report on the Development of the Mineral, Metallurgical, Agricultural, Pastoral, and other resources of Colorado for the years 1881 and 1882," p. 69, Denver, 1883.

13,169,761, or within $815 of the *Herald's* estimate. It is uncertain which is correct, but from these estimates it may be deduced that the production of Leadville in 1881 was about:—gold $300,000, silver $10,300,000.[1]

The Bassick Mine, which is situated six miles east of Silver Cliff, in Custer County, has always exhibited such very peculiar features as to render it one of the most remarkable in Colorado. It is situated near the centre of a small rounded hill composed of trachyte and felspathic conglomerate, of which the greatest diameter is, at its base, about 1,200 feet, while its height above the general level of the surrounding country does not exceed 200 feet.

Mr. L. R. Grabill,[2] who has recently described this remarkable deposit, states that an outcrop of fine-grained conglomerate is exposed on the south-west side, while on the north-east the hill joins, by an upward slope, the fine grained felspathic rock of Mount Tyndall, which rises some 600 feet higher, and of which the elevation containing the Bassick Mine forms an arm.

On visiting this mine attention is immediately attracted by the unusual method of arrangement of the ore, which is seen to be disposed in concentric layers around fragments of trachyte. These fragments, each of which constitutes a nucleus for a concentric arrangement of deposits, vary in size from boulders having a diameter of two feet, to pebbles whose diameter is not greater than half an inch. These have no sharp or rough edges, but have evidently been much worn by friction before the deposit of the metalliferous minerals took place, their shape being usually approximately spherical. They consist of trachyte precisely similar in character to that of the country rock, of which they are, without doubt, a portion. These, with their coatings of ore, quartz, and kaolin, constitute the greater portion of the filling of the fissure, and when separated from the surrounding layers of ore they rarely show by assay anything beyond a trace of the precious metals.

As before stated, around each of these waterworn fragments, as a nucleus, are arranged concentric layers of ore, each particular mineral forming a separate stratum. The layers always follow one another in the same order, are of about the same proportionate thickness, and are all parallel to the surface of the

[1] "Report of the Director of the Mint upon the Production of Precious Metals in the U.S." p. 416, Washington, 1882.

[2] "On the Peculiar Features of the Bassick Mine," *Trans. Amer. Inst. Mining Engineers*, vol. xi. 1882, p. 110.

nucleus. Usually three, but sometimes four, distinct layers are seen firmly attached to one another, but with the line of separation perfectly visible. The stratum next the nucleus, which is invariably the thinnest, consists of sulphides of zinc, antimony, and lead; this layer varies from the thickness of a sheet of paper, in the outer portion of the ore body, to some two and a half inches nearer its centre, but is usually from $\frac{1}{60}$ to $\frac{1}{30}$ inch through. This stratum contains about 60 oz. of silver per ton and from 1 to 3 oz. of gold, but varies much in composition. Next to this coating a second is often found, which, although it is not always very distinct, is lighter in colour, slightly thicker, and contains more lead, silver, and gold than the previous one. This coating frequently contains as much as 100 oz. of gold per ton, and from 150 to 200 oz. of silver. The third shell, counting from the nucleus outwards, consists of blende from a quarter of an inch to two and a half inches thick; this mineral, which is usually crystalline, generally contains from 60 to 120 oz. of silver per ton, with from 15 to 50 oz. of gold, and constitutes the principal source of value in the mine. It contains also a considerable amount of iron and copper sulphides. The inner surface is smooth, but the outer is rough, with the points of the crystals projecting. The fourth coating, when there is one, is formed of chalcopyrite, and varies much in quantity. Sometimes it consists merely of crystals, sparsely scattered over the rough pointed surface of the blende, while at others it attains a thickness of three quarters of an inch. This contains as much as 100 oz. of gold per ton, and about the same amount of silver. Outside of this there is occasionally, though rarely, a fifth thin coating or sprinkling of crystalline iron pyrites.

Surrounding all, especially in the larger cavities, but not usually in the smaller ones, near the outer edges of the ore body, kaolin is found. This exists, however, not as a coating, but rather as completing the filling of the crevices between the boulders. The fragments of rock which these minerals surround, are not necessarily in close contact, nor do they fit into one another in any way; they resemble in general disposition a loose pile of water-worn stones which have been carelessly thrown into a pit, and have afterwards become coated with thin metalliferous coverings. A peculiar fact regarding this deposit, and one which is somewhat difficult to explain, is that the nuclei or barren fragments are rarely in contact with one another, while the metalliferous envelopes surrounding them are in immediate contact. Thus, where actual contact between the boulders themselves might be expected, there are frequently found at the point of approximate meeting, two separate layers of ore, one belonging to each of the contiguous nuclei.

The only other mine in the district known to exhibit a concentric arrangement of minerals around a barren nucleus is the Bull-Domingo, seven miles from the Bassick. But there the ores and country rock are different; galena and spathic iron ore having been deposited around a nucleus of syenite, and the ores contain practically no gold.

The fissure, which in itself constitutes one of the peculiarities of the Bassick Mine, is an irregular opening, nearly elliptical in horizontal section, but varying in width, its shorter diameter being sometimes as small as twenty feet, while the larger approaches to one hundred. It has been found that for over eight hundred feet its downward direction very closely approaches the vertical; in horizontal direction it has no well-defined outline. There are not, as in ordinary fissures, any signs of a wall of country rock, and no continuations or extensions of the ore body have been found.

The ore is richer towards the centre of the body, the layers, called "scales" by the miners, being there thicker, and contain a larger proportion of the precious metals; but, as the edge is approached, it thins out and gradually becomes poorer, until at last it is too poor to be worked advantageously. From the centre of the body outwards, the fragments decrease in size and the layers of ore become thinner. Continuing the outward course, but without having passed any particular line marking a boundary, a conglomerate is reached, composed of small rounded pebbles of felspathic rock cemented by a hardened trachytic paste, but containing no ore. In the same manner, without finding any defined boundary, the country rock is reached. This is of the ordinary character, is grey in colour, and is of the same nature on all sides of the ore body.

The other products of the mine, occurring in subordinate quantities, are :—calamine, silicate of zinc, jamesonite, tetrahedrite, tellurides of silver and gold, free gold, quartz and graphite. The carbonate of zinc and electric calamine are found only among the upper or oxidized ores above the water level, and are doubtless the result of the decomposition of blende. Above the water level most of the free gold is found in wires and other usual forms. Tetrahedrite never occurs as a coating, but always filling vacancies between the coated boulders, and is usually found intermingled with quartz. In the same mass are also tellurides of gold and silver.

The quartz in this mine would appear to be a residue from the decomposition of silicates by impregnating solutions, and is found, like the tetrahedrite, occupying open spaces outside the coated boulders, and never within them, serving to some extent as a cement to hold the mass together. This quartz is, for the most part, amorphous, rarely showing any traces of crystallization; when it does so it is amethystine, but more frequently it appears to have been deposited in a gelatinous state.

One of the most striking features of this mine is, however, the existence in it of graphite. This is found in cavities between the coated boulders, and toward the outer edges of the ore body, but it is not necessarily adjacent to ore. It does not often occur, but has been found both near the surface and at great depths. Mr. Grabill is inclined to the opinion that this deposit has been the site of a geyser or mineral spring, carrying minerals in solution in its waters.

Gilpin County is the smallest in Colorado, but, with the exception of Lake County, has been the most productive of bullion. Its dimensions are somewhat less than fifteen miles by twelve, and its principal gold mines are situated in groups within an area of less than sixteen square miles. Mining was commenced in this area some twenty-three years since, and during the period which has since elapsed the production has been $41,000,000, of which $37,500,000 has been gold, and $3,500,000 silver, the whole constituting more than one-fourth of the entire bullion output of the State, and nearly two-thirds of the gold produced. The geology of many of the mining districts is very simple, the area being generally granitic, with occasional patches and dykes of various eruptive rocks. The granitic series embraces all the forms, from true massive granite, through the various gneissic rocks, down to highly stratified mica schist. The veins are mainly true fissures, having a strike often approximately north-east and south-west, though there are instances where the strike is either nearly north and south or east and west. Tellurium and tellurides occur in the ores of Boulder County and in various other localities in Colorado.

The following figures give the bullion yields of the principal mining counties in this State during the year 1882:—

Lake	County	$17,131,853
Gilpin	„	2,006,516
Clear Creek	„	2,001,629
Summit	„	1,150,000
Custer	„	705,116

The production of precious metals in Colorado during the census year was:—gold $2,699,900, silver $16,549,274.

The metallic production of Dakota is almost entirely derived from the region of the Black Hills, and in great part from Lawrence County. Nearly the whole yield is obtained from gold-bearing lodes, the gravel deposits being of very secondary importance. The gold quartz, which is of low grade, is reduced in amalgamating mills of great size and power, by which a large proportion of the gold present in the rock is extracted. Silver ores were discovered in Dakota almost as early as were those containing gold, but the comparative ease with which the latter can be worked led the early miners to neglect, to a great extent, the ores of silver. The principal group of quartz mines is that in the Homestake district, the reputation of which has long been established. The most important mines belonging to this group are the Homestake, Highland, Deadwood Terra, De Smet, Giant and Old Abe, Golden Star, Palmetto, American Flag, Lincoln, Amicus, Prince Oscar, Nettie, May Booth, Independence, Mineral Point, and Pea Warmer. The deepest shaft is upon the Giant and Old Abe, 450 feet. The quartz from the Homestake is taken from the 240-foot level, and yields about \$5·50 per ton. That from the Deadwood Terra is said to average \$4, and that from the De Smet about \$3·50, per ton. The mills of the Homestake Mining Company are stated to be capable of reducing 3,000 tons of quartz daily, at an average cost of \$1 per ton.

The amounts of gold and silver produced in the Territory, as reported by the Census Bureau, during the year ending May 31st, 1880, was:—gold \$3,305,846, silver \$70,813. Of the total quantity of gold only \$47,700 was yielded by placer mines. The production of gold and silver in 1881 is estimated by the Director of the United States Mint to have been \$4,000,000.

Until very recently Montana was entirely isolated from the Eastern States except by a long and tiresome coach journey in winter, or by tedious river navigation during a few months in summer. There is now, however, railroad communication to within seventy miles of Helena, connection being made over the Utah and Northern with the Union and Central Pacific roads at Ogden. Owing to want of facilities for transport, &c., the mining regions of Montana have been but little known to the outside world, and foreign capital has not found its way into the country. Fifteen years since the richest placer mines known were worked in this Territory, but until recently quartz mining was prosecuted only in a desultory and unscientific manner.

In addition to gold, silver, and lead, the copper ore sent forward from the numerous mines of Montana will, it is anticipated, in the future, form no inconsiderable item in the metal markets of the world. The production of gold and silver in the Territory during the year ending May 31st, 1880, was, of the former metal $1,805,768, and of the latter $2,905,066. Mr. R. B. Harrison estimates the yield of Montana, for the year 1881, at $6,050,000. This, however, doubtless embraces the value of the associated lead and copper, and the amount should consequently be reduced to $4,960,000, of which $2,330,000 will be gold, and $2,630,000 silver.

The most important mineral-producing portion of New Mexico hitherto explored is Grant County, situated in the extreme southwestern extremity of the Territory. The first discovery of gold made was in 1859 near Pinos Altos. These placers are represented to have been for some time very rich, and washing upon a small scale is still carried on, but principally by Mexicans. In addition to placer mining, much work has been done upon lodes in the contiguous mountains. The amount of gold produced in this district in 1881 was approximately $25,000, about equally divided between the placer and the quartz mines. Numerous silver mines have for many years been worked, intermittently, in the vicinity of Silver City, and have, in the aggregate, produced considerable quantities of bullion; silver mining is not, however, so actively carried on in the district as it appears to have been two or three years since. The mines in the Georgetown district are reported to be rich in ores of medium grade, and will be worked as soon as the cost of working minerals of that class shall have been sufficiently reduced to admit of their profitable treatment. Some other portions of the county hitherto imperfectly prospected, must await the period when explorations in distant portions of the Territory shall have become a less hazardous pursuit than it now is.

In addition to Grant County one or both of the precious metals have been produced in Doña Aña, Socorro, Santa Fé, and Colfax Counties. According to the report of the Director of the United States Mint, the figures in the table on page 553 represent the total estimated production of New Mexico since its annexation by the United States, as also the yield for the year 1881.

Although Wyoming is surrounded on three of its sides by important mining regions, there are but few developed mines within its boundaries. As far as can be ascertained, the actual production of gold during the census year was confined to Sweetwater County, which yielded gold to the value of about $17,320.

The total production of bullion in the division of the Rocky Mountains during the year ending May 31st, 1880, was:—gold $7,878,189, silver $19,917,490.

BULLION PRODUCTION OF NEW MEXICO.

Counties.	Total production.		Yield during 1881.	
	Gold.	Silver.	Gold.	Silver.
	$	$	$	$
Grant	6,500,000	3,502,000	25,000	275,000
Doña Aña	100,000	100,000	—	—
Socorro	—	20,000	—	—
Santa Fé	—	—	10,000	—
Colfax	3,750,000	—	150,000	—
Totals	10,350,000	3,622,000	185,000	275,000

EASTERN DIVISION.—This group, which comprehends Virginia, North Carolina, South Carolina, Georgia, Alabama, Tennessee, Maine, Michigan, and New Hampshire, although the oldest, is the least productive of the three divisions.[1] The first notice of the discovery of gold in the Southern States occurs in Jefferson's *Notes on Virginia*, in which it is stated that a lump of that metal weighing 17 dwt. had been found near the Rappahannock; and Dayton, in his *View of South Carolina*, published in 1802, mentions the finding of a small piece of gold on Paris's Mountain. In 1799 gold was found in Cabarrus County, North Carolina, and placer washings upon a small scale were carried on both there and in Montgomery County for several years. These operations, which were entirely restricted to the washing of sands and gravels, yielded in addition to gold-dust, several nuggets of considerable size, one of which, found in Cabarrus County, weighed 28 lbs. avoirdupois.

The first United States gold was coined at the Mint in 1825, and from that time up to 1830 four-fifths of the gold coined in the country was of native production. From 1804 to 1827 North Carolina furnished the whole of the gold produced in the United States, amounting to about $110,000, but in 1829 Virginia contributed $2,500, and in the same year South Carolina yielded $3,500. In 1830 Georgia made its first deposit of gold at the Mint, amounting to $212,000. Previous to 1825 all the gold of

[1] J. D. Whitney, "Metallic Wealth of the United States," 1854, pp. 114–134; W. J. Henwood, "Metalliferous Deposits," pp. 371–384, Penzance, 1871; E. Motz and T. M. Chatard, "The Brewer Gold Mine," New York, 1880.

North Carolina had been obtained from shallow washings, but in that year auriferous veinstone, containing a large amount of gold, was discovered *in situ*, and this had the effect of turning attention from "deposit mines" to "vein mines."

The Appalachian Chain takes its origin in Canada, south-east of the St. Lawrence, and forms a series of mountain ridges extending in a south-westerly direction into Alabama. Its width, which is very variable, is greatest near its centre, gradually diminishing towards the ends. It is divided into a number of parallel ridges, and has a total length of some 1,300 miles. Along the south-eastern edge of this series of parallel mountain chains, lies an undulating range of elevations known by different names in the various States through which they pass. In Vermont they are known as the Green Mountains, in New York they are called the Highlands, in Pennsylvania the South Mountains, in Virginia the Blue Ridge, and in North Carolina the Smoky Mountains. This belt, which is composed of metamorphosed rocks of Lower Palæozoic age, varies from ten to fifteen miles in width, and contains few distinguishable fossils. Immediately to the south of this lies the auriferous belt, running nearly parallel to the Blue Ridge and apparently of the same geological age. In Virginia the central axis of this band has a direction of N. 32° E., but still further north it follows a line more nearly approaching east and west. Its width, where most developed, on the borders of North and South Carolina, does not exceed seventy miles.

Beyond Maryland the auriferous belt is no longer continuous, detached patches only being, from time to time, met with until Canada is reached, where there is a considerable area containing gold. The rocks throughout the whole of the auriferous belt closely resemble one another, and consist of schists of almost every variety alternating with bands of granite and syenite. The predominating rock is a talcose schist sometimes passing into the chloritic and argillaceous varieties. The talcose schists which predominate in the gold-mining districts of Virginia have usually a reddish colour, are often fissile, and have a general strike of about 30° N. of E. For the most part the laminæ of these rocks are almost vertical, and enclose bed-like veins of quartz, together with masses of granite, syenite, and protogine. The gold almost invariably occurs in quartz, which, near the surface, is cellular, and stained either red or brown by the oxidation and removal of iron pyrites, with which the precious metal is often associated. In the immediate proximity of the gold-bearing beds, which strictly conform to the schistose structure of the enclosing rocks, the schists frequently assume a thick lamellar aspect, although in other situations they are usually more fissile. The ore-bearing deposits are, for the most part, composed of an intimate mixture of quartz and slate, in which are sometimes embedded distinct and well-defined masses of either the one or the other. Angular and vein-like bodies of translucent or milk-white quartz, surrounded by a coating of brown or red iron ore, are also occasionally met with. Small quantities of auriferous iron pyrites, magnetite, and yellow copper ore, together with a little free gold, are irregularly disseminated through layers of more or less ferruginous quartz, and still more sparingly through the adjoining slaty rocks.

One of the most remarkable auriferous deposits of the States on the Atlantic sea-board is that known as the Brewer Gold Mine, situated on Lynch River, Chesterfield County, South Carolina. The mode of occurrence of the precious metal in this locality will be understood on referring to the accompanying transverse

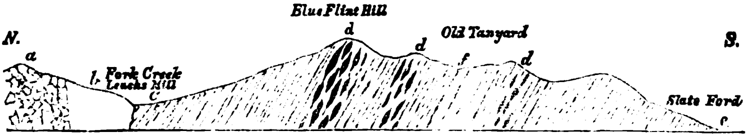

FIG. 89.—The Brewer GOLD Mine; section.

section, Fig. 89, reduced from a drawing of Professor Lieber.[1] In this section, which represents a length of about three miles, *a* is a dyke of coarse-grained granite, south of which is a band of trachyte, *b*, abutting against the talcose slates, *c*, which contain three distinct and parallel bands of lenticular deposits, *d*, as well as some small branches of barren white quartz; *e* is clay slate seen at the Slate Ford, while at *f* is the auriferous detrital deposit known as the Old Tanyard. Of these three groups of lenticular veins the two northern ones only have been worked, the third remaining almost in its original condition.

The direction of these veins exactly corresponds both in strike and dip with the bedding of the enclosing slaty rocks, and their breadth varies from twenty to fifty feet. These lenticules consist of a blue hornstone which is seldom found in an undecomposed condition, and is never met with in a fresh state except in the centre of the reniform masses constituting the deposits. The

[1] "Report on the Survey of South Carolina," 1858, p. 63.

hornstone contains finely disseminated iron pyrites and yellow copper ore, by the decomposition of the former of which the disintegration of the mass would appear to have been chiefly effected; enargite and cassiterite are also present in subordinate quantities. The whole of the hornstone of the lenticular masses at the Brewer Mine is auriferous, but is traversed in every direction by veins of white quartz containing no gold.

The Tanyard, where the first gold was discovered, is an extensive detrital deposit, lying in a valley, and evidently resulting from the disintegration and removal by water of the auriferous lenticules on either side. A shaft and a tunnel, which, according to tradition, were made previous to the War of Independence, are still visible, but the presence of workable gold in this locality appears to have been first made known by Brewer, who discovered it at the Tanyard in the year 1828.

For many years these disintegrated gravels were leased in plots, each usually twelve feet square, which the lessees worked when and in what way they thought proper, paying to the proprietor of the soil a royalty of one-fourth of the gold extracted. The ill-directed labour thus expended was for a long time remunerative to all parties, but the disadvantages arising from such an entire lack of system at length became so great that, about five years since, the property was for the first time worked as a whole by the hydraulic system. The discovery of tin ore in the sluice-boxes of this mine is interesting rather on account of the peculiarity of its occurrence than for its commercial value. The crystals of this mineral are often well formed, and are not unfrequently studded with crystalline particles of gold.

According to the report of the Director of the United States Mint, South Carolina suffered in 1881 from a drought, which materially interfered with gold mining generally. The Brewer Mine fully answered expectations, and would have produced from $25,000 to $30,000 during the year, had not the lack of water, in the month of August and subsequently, brought the work almost entirely to a standstill.

According to official statistics the production of the gold-fields of the eastern division of the United States amounted, during the year ending May 31st, 1880, to only $239,646.

The total production of each State and Territory, including the yield of the deep mines from ore raised prior to, but reduced during, the census year, and also the silver contents of placer gold, is given in the following table.

TABLE SHOWING THE WEIGHT AND VALUE OF THE PRECIOUS METALS PRODUCED IN THE UNITED STATES DURING THE CENSUS YEAR ENDING MAY 31ST, 1880.

State or Territory.	Production. Gold.	Production. Silver.	Total Value.		
	oz.	oz.	$	£	s.
Pacific Division.					
Alaska	288	39	6,002	1,200	8
Arizona	10,254	1,798,921	2,537,792	507,558	8
California	829,676	890,159	18,301,840	3,660,368	0
Idaho	71,578	359,309	1,944,205	388,841	0
Nevada	236,468	9,614,562	17,318,913	3,463,782	12
Oregon	53,101	21,497	1,125,493	225,098	12
Utah	14,106	3,668,564	5,034,645	1,006,929	0
Washington	6,569	788	136,819	27,363	16
Totals	1,222,040	16,353,839	46,405,709	9,281,141	16
Division of the Rocky Mountains.					
Colorado	130,608	12,800,119	19,249,174	3,849,834	16
Dakota	159,920	54,770	3,376,659	675,331	16
Montana	87,354	2,246,939	4,710,834	942,166	16
New Mexico	2,387	303,455	441,691	88,338	4
Wyoming	838	—	17,321	3,464	4
Totals	381,107	15,405,283	27,795,679	5,559,135	16
Eastern Division.					
Alabama	63	—	1,300	260	0
Georgia	3,920	257	81,362	16,272	8
Maine	145	5,569	10,200	2,040	0
Michigan	—	20,000	25,858	5,171	12
New Hampshire	532	12,375	27,000	5,400	0
North Carolina	5,755	108	119,095	23,819	0
South Carolina	631	43	13,097	2,619	8
Tennessee	97	—	1,998	399	12
Virginia	451	—	9,322	1,864	8
Totals	11,594	38,352	289,232	57,846	8
Summary.					
Pacific Division	1,222,040	16,353,839	46,405,709	9,281,141	16
Division of the Rocky Mountains	381,107	15,405,283	27,795,679	5,559,135	16
Eastern Division	11,594	38,352	289,232	57,846	8
Totals	1,614,741	31,797,474	74,490,620	14,898,124	0

QUICKSILVER.

The quicksilver-bearing belt of California[1] extends over a distance, in a general north and south direction, of about three hundred miles, and is occupied by massive beds of slate accompanied by gabbros or by calcareous and siliceous beds, and is broken through and not unfrequently capped by eruptive rocks. Wherever they come to the surface these slates are found to be generally more or less impregnated with mercury, either in the form of cinnabar, or in the native state. Selenide of mercury is also occasionally found. These slates extend from San Luis Obispo to the north of Sonoma, and re-appear in Trinity County. Accompanying them, on the south, are calcareous and magnesian rocks of various ages, while at the north, and towards the centre, are sandstones and serpentines. Throughout this band, which is sometimes above half a mile in width, quicksilver ores occur as impregnations in the calcareous and siliceous rocks, and as beds or deposits in the slates. The distinction between impregnations and beds is not, however, always well defined, since many of them might, apparently, be the result either of sublimation or of infiltration. Mercury has been worked as far south as the County of San Luis Obispo, where the most massive ore is found in compact talcose slate, hornstone, and greenstone. The cinnabar is accompanied by much iron pyrites, and is distinctly crystalline.

The New Almaden Mines, in Santa Clara County, are worked upon a number of segregated deposits enclosed, chiefly, in a belt of altered slates, with lenticular masses of serpentine lying on either side. These slates belong to the Cretaceous age, but in California the occurrence of cinnabar is not confined to any particular geological horizon. In these mines the ore occupies a series of irregular cavities confined within a comparatively small space, both horizontally and in depth; the chimneys occurring without any approach to regularity, and often without any visible connection with one another.

At the Enriquita Mine a series of irregular bodies of cinnabar, and a number of nearly parallel seams of the same mineral, are enclosed in a soft decomposed ochreous breccia containing fragments of siliceous limestone with pieces of jasper and chalcedony.

The New Idria Mines, in Fresno County, consist of a number

[1] R. W. Raymond, *Statistics of Mines and Mining*, 1874, p. 379; *Ibid.* 1875, p. 13.

of workings distributed along a course some three miles in extent between San Carlos and New Idria proper. At the San Carlos workings the rock is a whitish granular sandstone, sometimes in its original condition, but, more frequently, to some extent metamorphosed, through which the cinnabar is irregularly diffused without any apparent system or order. At the Aurora, lying between the San Carlos and the New Idria Mines, the rock is hard and siliceous, frequently coloured by iron, and containing occasional specks of cinnabar. At New Idria proper the rocks are exceedingly varied, but consist chiefly of sandstones and slates in different stages of metamorphism. In one of the main tunnels of this mine the rock is a dark, somewhat bituminous slate, much fractured, exhibiting numerous slickensides, and so disturbed that it is impossible to determine either its average dip or direction. In other parts of the excavations the rock is very siliceous and is broken into a sort of breccia, cemented by the cinnabar, which fills the spaces between the fragments.

At p. 68 I have mentioned the occurrence of cinnabar and sulphur at the Sulphur Bank, in Lake County, California, which I visited in the year 1866. At that time the deposit was worked exclusively for sulphur, but it has since been successfully opened as a quicksilver mine. Believing that additional light on so interesting a subject would be welcomed by the scientific world, Messrs. Le Conte and Rising, of the University of California, made repeated visits to this mine during the years 1877, 1878, 1879, 1880, and 1881, and have recently published the results of their observations, made down to a considerable depth below the volcanic capping, to which my examination was necessarily confined.[1]

At the time of their earlier visits, namely from 1877 to 1880, the underlying country rock could be reached and examined in only one excavation, known as the "Waggon-Spring Cut," but in the summer of 1881 they had an opportunity of examining the stratified rocks underlying the lava to a depth of 260 feet. Since their previous visit a shaft had also been sunk some distance to the south of the Waggon-Spring Cut, about 150 feet outside the limits of the lava-flow, with the intention of reaching the ore body by means of drifts, the uppermost of which had been driven for a distance of 150 feet. Mr. W. Jackson, of San Francisco, who examined the volcanic rock, determined it to be an

[1] Joseph Le Conte, and W. B. Rising, "The Phenomena of Metalliferous Vein-formation now in progress at Sulphur Bank, California," *American Journal of Science*, vol. xxiv. 1882, p. 23.

augite-andesite. The stratified rocks in its vicinity, where not concealed from view by a capping of lava, consist of sandstones and shales inclined at very high angles.

The phenomena observed were as follows:—For seventy or eighty feet from the shaft the rock is barren sandstone and shale, dipping to the south, and comparatively dry and cool. Then it becomes brecciated and highly charged with ascending hot water containing a large amount of alkaline sulphides, with excess of CO_2 and H_2S. In the hottest places the temperature of the water is 160° Fahr., and CO_2 bubbles up so profusely that a lighted candle near its surface is quickly extinguished. The heat of the freshly cut rock is often too great to be borne by the naked hand, and in this hot shattered rock the ore is found. The mine is worked with difficulty on account of the almost insupportable heat, but this has now been, to a great extent, removed by the more complete ventilation recently introduced. The lower drift had not at the time of their visit yet reached the ore body.[1]

The brecciated layer which forms the water-way is here, as in the Waggon-Spring Cut, composed of fragments of sandstone and shale, usually angular, but sometimes sub-angular, as if the edges had been either worn or dissolved away. In some places, where the ascending water is abundant, there is hot mud only between the fragments, but in others, where the rock is drier, and the solfataric action is exhausted, the fragments are firmly cemented by a paste of consolidated mud containing disseminated metallic sulphides, or wholly by deposits from solfataric waters. The vein thus becomes a mere breccia united by a paste of cinnabar, pyrites, and silica, but chiefly by cinnabar. The spaces are sometimes entirely, and sometimes only partially, filled with the deposit, occasionally leaving hollows between the fragments. In this case the mass may have the appearance of an aggregation of pellets of cinnabar, but on breaking them they are found to have an angular fragment of rock as a nucleus. The deposit lining or filling the cavities is most commonly cinnabar, but sometimes consists of iron pyrites, or silica, or of all three arranged in alternate layers. The silica was found in all stages of consolidation; sometimes chalcedonic, sometimes cheesy, and sometimes gelatinous. The vein or deposit is largely enclosed in the

[1] In 1882 the work was progressing on five different horizons, namely:—104-foot, 157-foot, 210-foot, 260-foot, and 310-foot levels. The third, 210-foot level, had been pushed 232 feet, cutting through the ore body, and reaching barren rock on the other side. The fourth level had been pushed 136 feet, and had reached the ore body. The varying dip at these levels shows that the strata are very much broken up.

brecciated stratum described, but is, apparently, not wholly confined to it. It is extremely irregular, sometimes widening out to many yards in extent, and then thinning down to a few inches, or even pinching out and disappearing entirely to again appear in a different stratum. Sometimes it is repeated, with barren rock between, while at others it leaves the brecciated layer and appears in the shattered sandstone either on one side or on the other. This deposit is in some places exceedingly rich, constituting a breccia united by a paste consisting entirely of cinnabar, which often constitutes more than one-half the weight of the entire mass. No free sulphur was found either here or at any depth beyond a few yards below the surface.

The New Almaden has been the most productive mine in California, and in 1863 yielded 40,391 bottles or 3,089,911 lbs. of quicksilver, but in 1873 the production had become reduced to 12,000 flasks, each containing on an average 76½ lbs.

The New Idria Mine, during the same year, produced 7,600 flasks of quicksilver, and the total production of California was estimated at 28,600 flasks.

LEAD.

Lead ores occur in the Atlantic States,[1] in true veins, enclosed in the Azoic slates of New York, &c., in the form of argentiferous galena, associated with blende, iron pyrites, and copper pyrites; in veins running parallel to the formation, especially in New England; and as irregular deposits in the unaltered Lower Silurian rocks of the State of New York and elsewhere. They are not, however, extensively worked, and exhibit no peculiarities of especial interest. The most important lead regions of the United States are those of the Upper Mississippi Valley and Missouri.

Lead ore was first discovered in the south-west by Le Sueur, who made a voyage up the Mississippi in 1700. The first mining appears to have been undertaken in 1788 by Dubuque, a half-breed Indian trader, and was carried on by him until his death in 1809; but it was not until 1827 that lead miners began to spread themselves over the Wisconsin lead region, from which time the quantity of lead produced rapidly increased until 1845; after which period, however, it again declined.

[1] J. D. Whitney, "The Metallic Wealth of the United States," p. 382; *Ibid.* "Report on the Upper Mississippi Lead Region," *Geol. Survey of Wisconsin*, vol. i. 1862.

The Upper Mississippi lead district is included within the boundaries of three States, namely, Wisconsin, Illinois, and Iowa, but about five-sixths of the lead-producing area belongs to Wisconsin. The deposits of lead ore are developed in the Galena or Upper Magnesian Limestone, of the Trenton period of the Lower Silurian formation, and extend over an area of some 140 geographical square miles. There are no deposits of lead in the valley of the Mississippi which can be considered as coming in any way under the head of true veins, as they are invariably limited in depth, and are enclosed in a geological formation of which the productive portion does not generally exceed a hundred feet in thickness. Whitney distinguishes various forms of these deposits:—The simplest variety is the *sheet*, the characteristic mode of occurrence of lead ores in the Mississippi valley, which is a solid mass of ore filling a vertical fissure; the ore remaining as it was first deposited, and the rock exhibiting no evidence of having undergone decomposition. The dimensions of such sheets are very variable, but generally the thickness does not exceed three inches, while their longitudinal extension is not great, usually varying from a few yards to a hundred. From twenty to forty feet may be considered the most usual limit in vertical extension; but in some instances a much greater depth has been attained while following down an unbroken mass of ore. In sheet deposits there are rarely any of the ordinary accompaniments of a true vein, such as gangue or veinstone, and the walls are never smooth or striated. Should the ore give out, the crevice becomes filled with clay, ochre, or calc spar, while quartz is never present.

An *opening* is the widening out of a crevice in strata in which the conditions are favourable to the accumulation of lead ore, and is filled with galena surrounded by ferruginous clay. When their dimensions are very irregular, the fissure contracting and expanding suddenly and frequently, so as to give rise to numerous isolated cavities of different sizes connected by the general line of fissure, the whole is called a *crevice with pocket openings.* The *cave opening* is a magnified form of the pocket opening. An expansion of this kind in Levin's Lode, near Dubuque, was 130 feet long, 45 feet high, and 30 feet wide. There are frequently great irregularities in the vertical height of such openings, which sometimes rise into conical cavities, called chimneys, often lined with stalactites of calc spar and galena. *Crevice openings* are chiefly confined to the upper portion of the Galena limestone, while in the lower portions of that rock *flat sheets* and *flat openings* occur as characteristic forms of deposit. The difference between vertical and flat sheets is one of position only. Flat sheets are made up of blende, calamine, and pyrites, associated with galena. Calcite and heavy spar are found, in some cases, as vein-stuff, while quartz is wholly wanting. In flat sheets the minerals are sometimes arranged symmetrically.

The principal ore in these deposits is a very pure galena, poor in silver (·001 to ·002 per cent.), crystallizing, principally, in cubes. It is frequently accompanied by blende and zinc carbonate, the latter being called *dry bone* by the miners, on account of its cellular, bone-like structure. Iron and copper pyrites are comparatively rare, but brown iron ore seems to constantly occur with the lead and zinc ores. Calcite and heavy spar are subordinate, while quartz and the compounds of lead with arsenic and phosphorus are entirely absent.

The occurrence of mammoth and other bones in crevices with the lead ore, as well as in the clay and sand near the surface, has been repeatedly noticed by those who have been engaged in investigating the geology of the lead region. Casts of fossils in sulphide of lead are not unfrequent in this region, a fact which is alone sufficient to demonstrate the aqueous origin of the ore.

The first mining operations in Missouri were commenced in 1720, the celebrated La Motte Mine being one of the most important opened at that period. The principal deposits are situated in Washington County, but there are some others in the Counties of Franklin and Jefferson. The geological position of the metalliferous deposits of Missouri is very similar to that of the Mississippi lead mines.

The total annual production of lead in the United States during the year 1882 was 132,890 tons, of which more than one-half was produced in the western States and Territories. In the year 1882, Colorado produced 58,642 tons of metallic lead, and Utah 30,000 tons of that metal.

ZINC.

Ores of zinc[1] are widely distributed over the United States of America, but, with the exception of those situated in New Jersey, its deposits exhibit no features of especial interest. At the Eaton Mine, in New Hampshire, there is a vein six feet in

[1] J. D. Whitney, "Metallic Wealth of the United States," p. 347; R. W. Raymond, "Zinc Deposits of Southern Missouri;" *Trans. Amer. Inst. Mining Engineers*, vol. viii. 1880, p. 165.

width, traversing altered Palæozoic rocks, which consists chiefly of yellow blende, enclosing masses of argentiferous galena. Ore of a similar character is found at the Shelburne Mine, and at various other localities in the same State. At Warren there is a thick bed of black blende, associated with galena and iron pyrites. In the State of New York zinc ores have been obtained from mines in the vicinity of Wurtsboro', in Sullivan County, where they occur in a bed parallel with the stratification of the Shawangunk Mountain. According to Professor Mather, it forms a segregated mass, varying from two to five feet in thickness, the larger portion of which consists of a siliceous rock, similar to that forming the roof and floor, containing fragments of greenish and blackish slates. The metalliferous constituents are blende, galena, copper pyrites and iron pyrites, associated with crystallized quartz. The leader of solid ore varies in thickness from a mere trace to three feet.

The zinc deposits of New Jersey are situated in Sussex County, on a range of hills, which, commencing near Sparta, extends in a southerly direction through Stirling to Franklin, where the deposits are worked. They occur in association with a white crystalline limestone, which can be traced from Orange County in the State of New York to beyond Stirling, and is probably of Lower Silurian age. An intrusive felspathic rock appears to form dykes in this limestone, which is tilted at a considerable angle. At Stirling Hill a bed of zinc ore rests with a steep south-easterly dip against a bed of franklinite, both exactly coinciding in dip with the bed of limestone in which they are enclosed. The ore consists of the red oxide containing 80·26 per cent. of zinc, and 19·74 per cent. of oxygen, and is found only in the State of New Jersey. The bed of franklinite on which the zinc ore rests varies from twenty to thirty feet in thickness. At Mine Hill, Franklin, the same succession of limestone and metalliferous beds is to be observed, but the intrusive rock is there said to be syenite, the blue limestone having been converted into a white crystalline mass along the line of contact of the two rocks, and in this both the zinc ore and the franklinite are intercalated in the form of beds.

Among the numerous deposits of zinc ore in the State of Pennsylvania those of the Saucon Valley, near Friedensville, are the most important. The ore there consists almost entirely of silicate of zinc, and is remarkably free from any admixture either of lead or iron. The deposits are in the form of included beds in a compact blue limestone of Silurian age, apparently the equivalent of the Calciferous Sandstone of American geologists.

Lead mining in Missouri appears to have been considerably affected by competition with the mines of the western States and Territories; but simultaneously with this depression the development of new zinc deposits has caused a revival in this branch of industry. The zinc-bearing region in south-western Missouri is very extensive, the ores being chiefly carbonate and hydrous silicate of zinc. The deposits in the north and south-east of the State are said to be in Silurian rocks, but those of the south-west are Sub-Carboniferous. This difference in age of the enclosing rocks does not, however, necessarily prove a similar difference in the age of the deposits. The Sub-Carboniferous limestone of the south-west is nearly horizontal, is characterised by numerous flinty segregations, and is occasionally shaly. In this formation occur the ore deposits, which are irregular in shape and distribution, although but little is known of their extent. They appear, however, to be limited in height, width, and length, and to abut in all directions against barren rock. Iron pyrites is plentiful in a few mines only, but in some of them the ore consists of a porous skeleton of silica, the pores of which are filled with blende. From this to solid flint rock, with disseminated specks of blende, all forms of transition are observed. The production of metallic zinc in the United States during the year 1882 is estimated at 33,765 tons.

TIN.

The occurrence of tin ore in the United States is so rare that the search for it has almost been given up as hopeless, some authorities going so far as to say that it would never be found in paying quantities. Tin ore has, however, been recently discovered in Alabama under somewhat promising conditions. During the past two years Mr. G. W. Gesner has been at work about two miles south-east of Ashland, Clay County, Alabama, putting up machinery preparatory to mining the tin ores found there. The property embraces nearly a square mile, and Mr. Gesner had recently forty-five stamps working.

At Winslow, in the state of Maine,[1] veins of cassiterite traverse an impure, grey, micaceous limestone, which is found in many parts

[1] T. Sterry Hunt, *Trans. Amer. Inst. Mining Engineers*, vol. i. 1873, p. 373.

of this region, and is subordinate to the gneissic series. The veins, which are seldom more than an inch or two in thickness, are abundant through a considerable extent of the rock, and are interlaminated with it, occupying spaces between the sedimentary layers, which are distinctly marked by different shades of colour; occasionally, however, they for a short distance cut across the stratification. The veinstone is purple fluor spar, white mica, and quartz. In this gangue the cassiterite is disseminated in small crystalline masses, sometimes half an inch in diameter, together with a little mispickel. Dana mentions scanty occurrences of cassiterite at Paris and Hebron in Maine, and at Chesterfield and Goshen in Massachusetts. But none of these deposits have hitherto proved commercially valuable. There is an occurrence of tin oxide in Missouri which seems to be a replacement of titanic oxide in sphene, but which can only be regarded as a mineralogical curiosity. Tin ore occurs in the Brewer Mine, Chesterfield County, South Carolina (see page 555), but apparently not in workable quantities.

Discoveries of stream tin have been made in Idaho, but no washings have yet been undertaken. Small pebbles of tin ore have also been found in Prickly Pear Creek, Montana. There is likewise a deposit of tin ore in the granite of the Temescal Range, San Bernardino County, California. Some rich specimens have been obtained from this locality, and during the winter of 1860-61 a great number of claims were taken up. This excitement has however long since subsided, and it may be concluded that the extent of the deposit was not large, since it would otherwise have probably been worked ere this. No tin ore of any commercial value was produced in the United States in 1881.

ANTIMONY.

Antimony occurs in the north-western portion of Sonora, where a short range of mountains, the Sierra del Alamo Muerto, skirts the eastern shore of the Gulf of California at about thirty miles from the sea, and fifty from El Altar. On the northern flank of this range an area of considerable extent is strewn with quartz and a heavy yellow mineral. The latter is said to have been long ago amalgamated for silver, but to have yielded so base an amalgam as to have been rejected as an ore of silver. Its true character appears to have been overlooked until recently, when samples were sent to England, and the value of the mineral as a pure oxide of antimony was at once recognised. Shortly afterwards arrangements were made with the owners to ship the ore for treatment to works erected at Oakland, California. There would appear to be three systems of veins within an area of about four square miles. The most northerly group, the San José, was in 1881 the most productive in antimony, but it carried no silver. The Santa Margarita group lies between the preceding and the Argentine group. Both the second and third groups are argentiferous, but the first, although containing no silver, was, when opened, richer in antimony than the two latter. The size and yield of the veins have proved very variable, but the area over which the mineral is found is so large, and the number of veins so great, that the district promises to be an important one, though, to what extent, more extended mining alone can determine.[1]

Ores of antimony likewise occur in the Coyote mining district, Utah Territory, where stibnite occurs in large quantities in the form of horizontal beds or layers, in a soft sandstone, which rises in precipitous bluffs on each side of the valley of Coyote Creek. This sandstone is underlain by a thin bed of limestone, and by a conglomerate of much worn and rounded quartz boulders, forming the base of the bluffs. The antimony occurs just above the junction of the sandstone with the limestone, and in some places has been found in the conglomerate; generally, however, the layers of antimony ore are enclosed in the sandstone. The thickness of these layers varies at different points from a few inches to about thirty inches. It may in some cases be thicker than this, and there are evidences of two or more beds, one above another. The workings have not yet sufficiently progressed to show the full extent of the beds as regards their thickness and number.[2] Sulphide of antimony was discovered in South-western Arkansas in 1873, and since that date three mines have been opened, from which a number of antimonial minerals have been obtained. The most extensive deposit is on the Stewart Lode, which was discovered in 1877, and courses N. 13° E., with a nearly vertical dip. This would appear to be one of the few localities in the United States where ores of antimony are found in workable quantities.[3]

[1] J. Douglas, Jun., *Engineering and Mining Journal*, March 4th, 1882.

[2] W. Blake, "Report upon the Antimony Deposits of Southern Utah," New Haven, 1881.

[3] C. P. Williams, "Antimony in Arkansas," *Trans. Amer. Inst. Mining Engineers*, vol. iii. 1875, p. 150; C. E. Wait, *Ibid.* vol. viii. 1880, p. 42.

COPPER.

The Lake Superior region[1] during the year ending June 1st, 1880, furnished 90·48 per cent. of the total amount of copper produced in the United States east of the 100th Meridian; but exclusive of the yield of the western States and Territories; California, Colorado, Idaho, Arizona, &c.

This is one of the most productive copper districts in the world, the metal occurring in masses in bedded trappean rocks associated with interstratified sandstones and conglomerates. The copper is found almost wholly in the native state, and occurs not only in veins but also disseminated in amygdaloidal and conglomerate rocks, on which some of the richest and most productive mines are worked. The Lake Superior copper belt extends from Keweenaw Point south-west to Wisconsin, and thence across the State to Minnesota. Its length is about 130 miles and its width six, occupying portions of the Counties of Keweenaw, Houghton, Isle Royale and Ontonagon. Beginning at the north-east many mines have been opened from Keweenaw Point to the south-west, including the celebrated Calumet and Hecla Mine in Houghton County. There are various mines in Ontonagon County, and others on Isle Royale in Lake Superior.

Keweenaw Point is composed of two distinct formations; on the eastern side are sandstones, while on the western is an enormous development of alternating trappean rocks and conglomerates. The relative ages of these formations has given rise to much discussion. Both have been referred to the Potsdam epoch by Foster and Whitney, and by Sir W. Logan to the Chazy; while Mr. Bell, of the Canadian Survey, considers the cupriferous rocks to be of Triassic age, thus agreeing with Jackson and Owen in a view afterwards abandoned by the latter. Pumpelly is of opinion that the cupriferous series was formed before the tilting of the Huronian beds, upon which it rests conformably; and that, after the elevation of these rocks, sandstone and shales containing fossils, which show them to belong to the Lower Silurian period, were deposited as products of the erosion of the older rocks. It is, however, still uncertain whether they should be referred to the Potsdam, Calciferous, Quebec, or Chazy epoch.

[1] J. D. Whitney, "Metallic Wealth of the United States;" Raphael Pumpelly, "Copper-bearing Rocks," *Geol. Survey of Michigan*, vol. i. 1873.

According to H. Credner,[1] copper occurs in this region in four different forms of deposit, namely:—

1st. In true fissure veins which traverse the melaphyres and amygdaloids and are only productive in those rocks, but become contracted and pinched when they enter the diorites, and are totally unproductive as soon as they pass into the conglomerates or sandstones. In such lodes masses of native copper, each weighing many tons, are found associated with native silver, quartz, calcite, laumonite, prehnite, apophyllite, natrolite, desmine, fluor spar, epidote, and chlorite.

2nd. As entirely or partially filling vesicles in amygdaloidal melaphyres, as is the case not only in the vicinity of the lodes but also at considerable distances from them. At the Copper Falls Mine the amygdules are often entirely filled with native copper, but, when their filling is not exclusively metallic, the copper is accompanied by native silver, calcite, quartz, chlorite, laumonite, prehnite, analcime, epidote, datolite, iron glance, &c.

3rd. As an accessory constituent of an epidote rock lying in irregular layers between the various sheets of melaphyres.

4th. As the cementing material, or an accessory portion of the cementing material, of a breccia occurring between the sheets of melaphyre. The Calumet and Hecla deposit is an example of such a metalliferous breccia.

Crystals of silver, free from copper, are not unfrequently found deposited on copper containing no silver, and the masses of native metal usually exhibit, with electrotype fidelity, an exact cast of the surfaces of the enclosing rocks.

When, as sometimes occurs, a mass of copper is met with, extending some twenty or thirty feet along the course of a vein, and weighing considerably above a hundred tons, its removal is attended by a certain amount of difficulty. In order to extract such a deposit of "mass copper," the rock is first stoped from one side of it, and the metal subsequently divided by means of cross-cut chisels, into fragments of such dimensions as to admit of being taken upon rollers to the shaft and thence raised to the surface.

The name of "barrel work" is applied to the smaller pieces of copper, each usually weighing a few pounds only, which are too large to go under the stamping mill, and are consequently picked out to be sent away in barrels. In the more productive mines, considerable quantities of this lump copper are obtained during the breaking and preparation of the "stamp work." It usually contains

[1] *Neues Jahrb. für Mineral.* 1869, p. 1.

from 60 to 70 per cent. of copper. The largest proportion of the cupriferous material, in all the mines of Lake Superior, consists, however, of stamp work, which requires to be broken into pieces of moderate size before being subjected to the operations of stamping and washing.

The production of the Lake Superior Mines, during the year 1882, amounted to 28,491 tons of copper, of which amount 16,027 tons were supplied by the Calumet and Hecla Mine alone.

Copper ores associated with quartz occur in true lodes in the State of Maine at Dexter, Lubec, Parsonsfield, and various other localities.

According to the Census Bulletin, during the year ending June 1st, 1880, three mines in Hancock County, employing ninety-seven workmen, produced 12,500 tons of rough ore, equivalent to 41½ tons of metallic copper, worth $10,125.

Several copper mines have been opened in the State of Maryland, particularly in the vicinity of Liberty and New London, in Frederick County. The ores, which principally consist of various sulphides, are enclosed for the most part in a mixture of talcose slate and limestone. At the Dolly Hide Mine, in this district, the workings are carried on upon a broad band of crystalline limestone, which, where best developed, is nearly 100 feet in thickness, and contains numerous parallel bands of ore mixed with a quartzose material coloured brown by the oxides of iron and manganese. The rock on each side of the belt of limestone is an argillaceous slate. At the Springfield Copper Mine, in Carroll County, copper ore, chiefly in the form of copper pyrites, occurs in a vein running N. 25° E., with, for the first sixty feet, a dip south-east, and then becoming nearly perpendicular. This vein is at the surface from twenty to twenty-four feet in width, and was originally worked for iron ore. At Mineral Hill, near Sykesville, there are four veins enclosed in talcose and chloritic slates. In 1880 one mine in Carroll County employing six men produced 82 tons of copper ore.

The copper ores of Missouri, as well as the lead ores, are chiefly contained in Lower Silurian strata, which have been deposited in depressions of the Azoic rocks. Copper ore was first discovered in Ste. Genevieve County[1] in 1863 by a German farmer, who had occasion to make a road from his house into the neighbouring valley, and while so engaged noticed pieces of a green-coloured

[1] Frank Nicholson, "A Review of the Ste. Genevieve Copper Deposit," *Trans. Amer. Inst. Mining Engineers*, vol. x. 1882, p. 444.

mineral, of which he collected specimens, which were subsequently forwarded to St. Louis for analysis.

The Ste. Genevieve copper deposit occurs in the second of the Magnesian Limestone Series of the Lower Silurian system and in the immediate vicinity of the mines this rock attains a thickness of upwards of 250 feet. East of this the Carboniferous system is met with, and continues to the river above Ste. Genevieve, while below the town Quaternary deposits occupy the area included between Dodge Creek, Mill Creek, and the Mississippi River. As far as can at present be determined, the copper deposit consists of two nearly horizontal beds of ore between strata of chert enclosed in Silurian limestone. The uppermost of the two known cupriferous horizons, and that from which nearly the

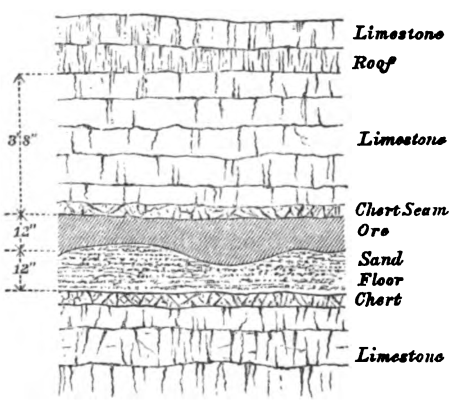

FIG. 90.—Ore deposit, Cornwall Mine ; vertical section.

whole of the ore hitherto extracted from the Cornwall Mine has been obtained, is 250 feet above the bed of the stream traversing the adjacent ravine. The lower level seam, that worked at the Swansea Mine, is at least 150 feet below the upper one. The principal ore is copper pyrites, which is found in a massive form, and varies in thickness from three inches to several feet. Fig. 90, after a sketch by Mr. Nicholson, taken in the Vallé drift of the Cornwall Mine, 250 feet from its mouth, shows the sequence and approximate thickness of the various strata in that locality. The ore is here compact copper pyrites almost free from gangue, but about fifteen feet from the point where this sketch was taken the ore seam is entirely lost, to again make its appearance at no very considerable distance.

During the census year, three mines in the County of Ste. Genevieve, employing eighteen persons, produced 1,051 tons of copper ore, representing 115 tons of ingot copper, worth $25,730.

The most important copper mine worked in North Carolina is the Ore Knob.[1] This mine is situated not far from the New River in Ashe County, North Carolina, and is on a true vein which cuts the strata of gneiss and mica schist of the region. These rocks dip 45° S.E., while the lode is vertical with a course N. 60° E. Both country rock and lode are decomposed down to considerable depths, the latter exhibiting a strong capping of gossan. At a certain depth the lode becomes charged with carbonate and red oxide of copper, which still lower down are replaced by rich sulphuretted ores of that metal. This deposit was worked irregularly before the Civil War, and was again opened in 1873. The outcrop has been traced for a distance of 1,900 feet, and copper ores have been met with in five different shafts within a distance of 661 feet. A drift has moreover been carried for the above distance through solid ore. The breadth of the lode varies from six to fourteen feet, and the outcrop of gossan is, in some parts, twenty feet in width. In 1874 the Ore Knob yielded a net profit of $60,302. Copper Knob, situated in the Blue Ridge, near the Ashe-Wautauga railway, is worked on a vein, or rather group of veins, of which the most important carries, in addition to quartz, erubescite, yellow copper ore, malachite, chrysocolla, specular iron ore and pyrites; with occasionally free gold and silver. Two mines, both situated in Ashe County, giving employment to 328 persons, produced, during the year 1879-1880, 24,680 tons of ore, representing 820 tons of metallic copper, value $350,000.

In Montgomery and Chester Counties, Pennsylvania, cupriferous veins occur at or near the junction of the gneiss and New Red Sandstone. This metalliferous zone extends in a general east and west direction across the Schuylkill River, occupying a range of country some six or seven miles in extent. Within this space there are ten or twelve lodes, some of which are said to be confined to one formation and some to the other; while others again traverse both. Professor Rogers states, as a general fact, that those veins which are confined chiefly or entirely to the gneiss bear lead ore as their most abundant mineral, while those which are restricted to the red shale usually contain more copper than lead.

[1] T. Sterry Hunt, "The Ore Knob Copper Mine," *Trans. Amer. Inst. Mining Engineers*, vol. ii. 1874, p. 123.

During the census year one mine in Montgomery County, employing ten hands, produced 289 tons of ore, representing 20 tons of ingot copper, value $5,630.

Numerous deposits of copper ore are enclosed in the Huronian rocks of South-western Virginia, East Tennessee, and Georgia. This belt, which extends over a length of nearly sixty miles, has been worked, to some extent, at three different points, namely:—Carroll County in Virginia; Ducktown in Tennessee, and Canton in Georgia. Of these deposits that of Ducktown has been the most extensively worked, and is consequently known to a greater depth and over a larger extent than is either of the other two.

The cupriferous deposits of Tennessee[1] are situated in the immediate vicinity of the Ocoee River, in the extreme south-eastern corner of the State. The ores are contained in micaceous schists, which dip at a high angle to the south-east, have a strike of N. 20° E., and enclose lenticular ore masses which may be followed, with but comparatively few interruptions, for a distance of five miles. These, which sometimes attain a very considerable length, with a thickness occasionally exceeding fifty feet, are at Ducktown arranged in three parallel zones separated from one another by bands of unproductive rock. According to Whitney and Credner, the metalliferous deposits of Ducktown are not only parallel to one another but also to the strike and dip of the enclosing rocks, and consequently in this respect resemble the great pyrites masses of Schmöllnitz, Rammelsberg, and Rio Tinto. Throughout the whole extent of their course these deposits exhibit a remarkable uniformity in their formation. The outcrop is usually rendered conspicuous by a heavy gossan, by which the surface of the ground is often covered with masses of ferruginous material over considerable areas. On sinking to a sufficient depth through this gossan, *a*, the section represented in Fig. 91 is obtained. Beneath the ferruginous outcrop is found a horizontal bed of cupriferous ore, *b*, of variable thickness, and of a width corresponding to that of the vein. Immediately under the copper ore, and separated from it by a well-defined line, is the unaltered veinstone, *c*, consisting of an intimate mixture of common iron pyrites, magnetic pyrites, and a little yellow copper ore, associated with quartz and, occasionally, with actinolite. This undecomposed veinstone contains on an average about 1½ per cent. of copper, but richer patches of

[1] J. D. Whitney, "Metallic Wealth of the United States," p. 322; H. Credner, *Berg. und. Hüttenm. Zeit.* 1867, p. 8; 1871, p. 370.

copper ore sometimes occur in the mass. The gossan, *a*, as well as the copper ore, *b*, mainly consisting of a mixture of the sulphides of iron and copper, often enclosing cubical crystals of iron pyrites, are evidently the result of the decomposition of the unaltered ore which once occupied their place. The sulphide of copper, forming a considerable proportion of the deposit *b*, has obviously been derived from the ore now converted into gossan; and, when stopping at Ducktown during the summer of 1857, I not only remarked that some of the springs in the neighbourhood of the deposits were highly charged with H_2S, but also that this gas was in unusual quantities present in the mines. I was also informed by Captain Pill, then manager of the Hancock Mine, that, on one occasion, some men who were working on the black copper ore were

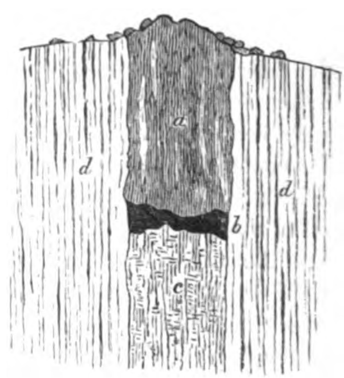

FIG. 91.—Section of vein, Ducktown.

for a short time driven from their work by a blower of sulphuretted hydrogen. Another indication of the process by which these deposits of secondary mineral are produced is furnished in the fact that, wherever the walls, *d*, of the deposits were crossed in the ore-bearing horizon by a fracture having a downward inclination, the fissure was invariably filled with copper ore of the class constituting the layer *b*. As before stated, the bottom of the bed of copper marks the limit of the decomposition of the vein, and beneath this line the ore exists in its original condition. The depth to which decomposition of the outcrop has extended is variable, but is nearly identical with that at which water is first found. On the ridges the depth of the gossan may average from eighty to ninety feet, but in the valleys the depth is not more than thirty feet. At one place in the Hiwassee Mine the body of black ore was forty-five feet in width, and Professor Whitney estimated its average thickness at two feet, although in many places it was much thicker.

At first the facility with which this ore could be mined, neither deep shafts nor timbering being required, enabled large quantities to be forwarded to Boston and elsewhere, in addition to that which was smelted upon the spot; but the beds of black ore became gradually exhausted, and at length nothing but the unaltered pyritic ore, *c*, remained. This has, at various times, been worked to considerable depths, but the results obtained do not, as a whole, appear to have been remunerative.

Dr. Hunt regards the Ducktown deposits as fissure veins, thus disagreeing with the opinions of Whitney and Credner, who believe them to be lenticular masses. Dr. Hunt has, however, had the advantage of a great additional development of the underground workings and also of explorations by the diamond drill, and he declares these deposits to possess a banded structure with interstitial spaces, and that they contain vugs characteristic of deposits posterior in origin to the enclosing rocks. During the census year only one copper mine was in operation in the State of Tennessee; this was situated in Polk County, gave occupation to four men, and produced 294 tons of ore, of which the percentage is not given.

According to Whitney, copper ores have been found in various localities in the State of Vermont. Copper pyrites comparatively free from iron pyrites occurs at Corinth, along a line extending about 1,100 yards, and bearing N. 10° W. A considerable quantity of the ore from this locality was formerly sent to smelting works in Boston. During the census year, Vermont contributed from one mine, in Orange County, employing 619 men and boys, 28,037 tons of copper ore, equivalent to 1,324 tons of ingot copper, value $469,495.

Copper ores occur in various places in Wisconsin, and among others in the neighbourhood of Mineral Point, where the ore occupies a fissure fourteen feet in width in Lower Silurian limestone. In 1841, in which year Mr. J. T. Hodge made an examination of this region, the fissure, which had been traced for a distance of about a quarter of a mile and to a depth of fifteen feet, was found filled with gossan enclosing lumps of green copper ore, beneath which was a mixture of clay and yellow ore. At that date about seventy-five tons of copper ore had been extracted from this deposit. During the census year, one mine in Iowa County, Wisconsin, produced 62 tons of copper ore, equivalent to 9 tons of ingot copper, value $1,549, and gave employment to seven men.

The total production in the United States east of the 100th meridian was, during the census year, 1,005,955 tons of ore, equivalent to 25,327 tons of ingot copper, worth $8,842,961.[1]

IRON.

Masses of specular and magnetic iron ore of enormous extent occur in the Laurentian and Huronian formations of North America.[2] Important ore masses of Laurentian age are found in the States of New York, New Jersey, and Pennsylvania; especially on Lake Champlain, in the highlands of New York, in New Jersey, and at Cornwall in Lebanon County, Pennsylvania. On Lake Champlain coarsely granular magnetic iron ore, which is sometimes rendered impure by the presence of apatite, occurs in lenticular beds interstratified in gneiss. In the New York and New Jersey highlands, syenitic gneiss contains beds of iron ore, which for many miles follow all the twistings and contortions of the gneiss. Magnetic iron ore is also found associated with the franklinite and red zinc ores of Franklin and Stirling, New Jersey. The most productive deposit of iron ore in the State of New York is at the Old Bed Mine, in Essex County, which in 1879-1880 yielded 208,416 tons, of the value of $744,344. The total output of iron ore in this State during the same year amounted to 1,262,127 tons. The number of iron-ore producing States is no less than twenty-three, and it will, therefore, be necessary to confine our attention exclusively to a few of the more important.

The magnetic ores of New Jersey occur in the mountain range in the western part of the State, and occupy an area

1 In the *Census Bulletin*, from which the statistics relative to copper have been chiefly derived, the yield is reduced to metallic copper, and its value is given at the mines, or at the point where it is no longer operated upon. In some instances both mining and smelting are carried on by the same establishment; while in others the process of reduction is partially carried on at the mine, and the product shipped in the form of regulus. In other cases the ores of copper are mined and shipped without any preliminary reduction. Thus the industry, strictly speaking, embraces both mining and smelting in a way which renders it impossible to separate the two. It follows that the only common unit to which these various products can be reduced is metallic copper, the value of which, to the mine producing it, varies greatly with the expense requiring to be laid out upon it before it reaches the market in the form of metal.

2 T. Sterry Hunt, "The Cornwall Iron Mine," *Trans. Amer. Inst. Mining Engineers*, vol. iv. 1876, p. 319; J. C. Smock, "The Magnetic Iron Ores of New Jersey," *Ibid.* vol. ii. 1874, p. 314; H. Newton, "Ores of Iron," *Ibid.* vol. iii. 1875, p. 360; R. Pumpelly and A. Schmidt, "Iron Ores of Missouri," New York, 1873; T. B. Brooks, "Iron-bearing Rocks," *Geol. Survey of Michigan*, 1873, vol. i. p. 9.

of 900 square miles, of which the average elevation is about 1,000 feet above the sea level. Excepting the valleys towards the north-western border, which contain magnesian limestone and Hudson River slate, the whole range consists of crystalline rocks closely resembling those of the Laurentian formation of Canada, distinct stratification being nearly everywhere observable. In the State Geological Survey Reports these rocks are described as Archæan, and it is in this crystalline metamorphic series that the magnetic iron ores are found.

In Sussex County, New Jersey, there is a unique deposit of franklinite, a mineral much resembling magnetite, but in which part of the iron is replaced by manganese and zinc. This is a valuable ore as a source both of zinc white and of spiegeleisen.

Deposits of magnetic iron ore pass from New Jersey into Pennsylvania, and are extensively worked at Cornwall, in Lebanon County. The great South Mountain belt is composed of Laurentian rocks, in which are found the characteristic ores of the Highlands of New Jersey, New York, and the Adirondacks; while Pennsylvania now produces large quantities of these ores, although the great area of ore-bearing Laurentian rocks within her borders still remains comparatively unexplored.

Another class of crystalline iron ores, chiefly magnetites, appears to belong to a distinct ore-bearing horizon, and is found in Pennsylvania along both borders of the Mesozoic Sandstone formation. These ores were referred by Professor H. D. Rogers to what he designated "Primal Slates," which he regarded as the lowest member of the Palæozoic series, though, by some later observers, the Cornwall Mine and certain related deposits west of the Susquehanna have been referred to the Mesozoic sandstones.

The area of ore exposed at the remarkable deposit of magnetite of the Cornwall Mine, measures about 4,000 feet in a direction nearly east and west, with a transverse breadth of from 400 to 800 feet, and includes three hills, separated by two valleys running north and south. These hills are due to a great ridge of eruptive rock, apparently dolerite, which, although now broken through by the valleys, was probably once continuous, and, having a curved form, has evidently served to protect the ore-bearing strata, which both on the east and west have been eroded and swept away in past geological ages. The ore is found in nearly horizontal beds, sometimes slightly contorted, and associated with layers of a greenish granular silicate, approaching hornblende in composition, and, more rarely, with a chloritic mineral or with serpentine. Besides these minerals, iron pyrites, which is sometimes cobaltiferous, copper pyrites, malachite and red oxide of copper, are occasionally met with. The facilities for mining are very great, the horizontal layers being worked in successive benches, forming wide terraces on the hill side, accessible to railways and locomotives. Into the middle hill two borings have been sunk to depths respectively of 240 and 335 feet below water level, the whole distance being in iron ore. The strata here offer but gentle inclinations, so that these measurements do not materially exaggerate the real thickness of the immense mass of ore lying beneath the surface. The Cornwall Ore Bank is the most productive iron mine in the United States, and in 1880 produced no less than 280,000 tons of ore, worth $500,000, and employed 135 miners.

But few localities from which iron ores are obtained in the United States possess a higher degree of interest than the deposits in the Archæan rocks of Missouri, among which the masses, chiefly of specular iron ore, worked at Iron Mountain and Pilot Knob are most conspicuous. There are also numerous beds of brown hæmatite in the Palæozoic strata capable of furnishing large quantities of good ore, some of which are being more or less actively wrought.

The Iron Mountain, Saint François County, is the largest deposit of iron ore in Missouri, and is surrounded by hills composed, mainly, of the normal brown porphyry of the district. A zone of red porphyry frequently mixed with iron ore runs along the northern side of the Iron Mountain, and separates the ore deposit from the brown prophyry on the other side. In the eastern portion of the zone the porphyry is partially decomposed, while at one point, near its contact with a blue porphyry, it occurs in distinct layers several inches in thickness, and has been sometimes mistaken for a limestone. The whole surface of the Iron Mountain is covered with surface ore of a similar character to that of the deposit itself. The main body of the hill consists of a loose clayey mass of decomposed porphyry, known as *bluff* (the mullock of Australian miners), which is cut into two nearly equal portions by a vein of specular iron ore of from forty to sixty feet in thickness, striking N. 53° E. This vein is known as the *backbone* of the Iron Mountain, but the *bluff* also contains numerous veins of from half an inch to ten feet in thickness, crossing the rock in various directions. The limits between these veins and the country rock are sharply and well defined. The ore of the Iron Mountain is very pure and almost free from mechanical admixtures of foreign matter. Certain extraneous substances, however, occasionally occur in it, such as fragments of porphyry, with crystals of apatite and quartz. The ore contains, on an average, 67 per cent. of iron.

In the accompanying section of Iron Mountain,[1] Fig. 92, *a* represents country rock, *b* iron ore, and *c* a fault.

In 1879-1880 the Iron Mountain employed 300 miners, and produced 144,153 tons of ore, worth $1,061,801; a value greater than that of the production of any other mine in the State.

Pilot Knob is a conical hill of nearly circular form, having a diameter at the base of about one mile. The rock is composed, chiefly, of more or less massively bedded porphyries, porphyry-conglomerates, and beds of hard specular iron ore, all of which are somewhat tilted. Their strike is about N. 50° W., and their dip

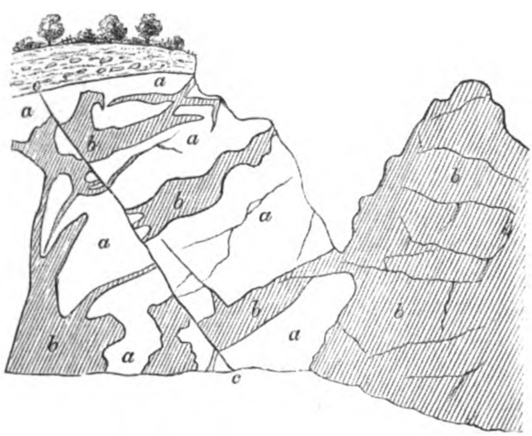

FIG. 92.—Iron Mountain; vertical section.

towards the S.W. The top of the Knob consists of stratified porphyry-conglomerate, with a thickness of 140 feet. This conglomerate is made up of pebbles of porphyry cemented together by iron ore, and also contains frequent independent layers and bodies of ore. The ore bed lies at the bottom of the conglomerate series, has a vertical thickness of forty-six feet, and is divided into two beds by a slate seam varying from ten inches to three feet in thickness. This seam, which is very persistent, lies thirty-one feet above the floor of the lower ore bed. The upper ore bed is more variable in thickness, having a regular floor, but no well defined roof. This bed of ore extends over an area of about 200,000 superficial yards.

[1] Pumpelly and Schmidt, "Iron Ores of Missouri," *Geological Survey of Missouri*, 1873, p. 10.

The Pilot Knob ore differs somewhat from most other specular iron ores in its colour being either steel grey or pearl grey, with a very marked tint of blue. Its lustre is faint and scarcely sub-metallic, while the structure is either crystalline or granular. The ore from below the slate seam contains an average of 60 per cent. of iron, while that above it averages about 53 per cent. of that metal. During the last census year, Pilot Knob produced 52,761 tons of iron ore, worth $115,993, and gave employment to 410 miners.

In the decomposed porphyry of Iron Mountain the ore often occurs in detached masses, which would appear to be segregations from a state of general diffusion throughout the rock. At Pilot Knob, on the contrary, the ore is distinctly bedded, and, although regarded by some who have studied the deposit as an impregnation of bedded porphyries, it is more probably a highly metamorphosed stratified deposit of iron ore.

The Huronian rocks of North America contain large masses of valuable iron ores, particularly in the Southern Atlantic States, and on the south shore of Lake Superior. In the Southern States the rocks containing the pyrites beds of Ducktown also enclose beds of magnetite, but they are of comparatively little industrial importance. On the other hand, the Huronian deposits of the Lake Superior region are, with the exception of those of Pennsylvania, the most productive in America. The iron-bearing rocks of Lake Superior correspond to the Huronian system of Canada, and consist of a series of extensively folded beds of diorite, quartzite, chloritic schists, clay slates, mica schists, and graphitic shales, among which are intercalated extensive beds of several varieties of iron ore. One of the most extensive, regular, and typical deposits of ore in the whole region is at the Champion Mine, thirty-three miles west of Marquette. The strike is here a few degrees S. of W., the dip 68° N., and the general form of the deposit that of a huge lenticular mass. The eastern portion of this is a black magnetic ore, while the western consists of a specular slaty ore containing some magnetite. Minor irregular deposits of pure ore, banded ore, and quartz, together with magnesian schists, alternate and form a comparatively regular deposit. Overlying the ore on the north side is a hanging wall of grey quartzite, and immediately south of it is a banded quartzose rock containing oxide of iron. Next towards the south, and overlying the whole formation, is a bed of diorite. In 1880 this mine produced 99,609 tons of ore, worth $355,748, and employed 350 miners. Granular and compact varieties of magnetic iron ore occur at the Michigamme Mine.

The ore bed is from seven to thirty-five feet in thickness, and extends for a great distance. The production during the census year was 66,158 tons, worth $212,652, and 197 miners were employed. The most productive undertaking, working deposits of a similar class, in this region is the Republic Mine, which in 1880 produced 224,000 tons of ore, worth $896,000, and employed 600 men. This is one of the largest masses of ore in the United States.

One of the most extensive, productive, and geologically interesting deposits in the Marquette Region is the Lake Superior Mine. The structure of the eastern half of this deposit is more complicated than that of any other in the district, and some questions connected with it still remain unsolved. In the western half is an ore-basin or trough, which abruptly narrows towards the west. The outcropping edges of this basin diverge rapidly, and its bottom falls in the same way, showing the deposit not to be a vein but a stratified bed similar to those of the enclosing rocks. In the eastern half there has been such a gathering together, crumpling, squeezing, and breaking up of the strata, as to nearly obliterate the stratification, and, instead of the quartzite hitherto found overlying all these deposits of rich ore, there is here a magnesian schist. The Lake Superior Mine produced in 1879-1880 215,930 tons of iron ore, worth $771,180, and employed 542 men.

The centre of the Menominee iron region is about fifty miles south-west of Marquette, and the same distance north of Menominee. The ores in this region occur in two parallel belts running east and west, separated by a broad granitic area. The southern belt is probably the most regular, and one of the most extensive iron deposits on the Upper Peninsula. Like their equivalents in the Marquette region, the ore strata of the Menominee district usually conform in their strike with the general trend of the beds, and dip at high angles. In the census year the county of Marquette, Michigan, alone produced 1,374,812 tons of iron ore, a total more than double that of any other county in the United States, or 17·25 per cent. of the entire production of the country.

Brown hæmatite is widely distributed in the United States, large deposits of this mineral occurring in the Palæozoic limestones of Tennessee, North Carolina, and North-western Georgia. The lignites of New Mexico, Colorado, and Montana, are often accompanied by brown hæmatite resulting from the decomposition of clay ironstones. This is also the case in the Appalachian region, and among the Carboniferous iron ore deposits of Ohio, Indiana, and Kentucky. Limonite occurs in dolomite associated with zinc ores in Arkansas, and Texas is also abundantly supplied with ores belonging to this class. The principal deposit of spathic iron ore in the United States is at Roxbury, Connecticut, where, in association with quartz, it occurs in a vein traversing gneiss. Blackband ironstone is of subordinate importance in America, but has been found in the Coal-measures of Western Pennsylvania. Earthy carbonates of iron ore are abundant in Pennsylvania, Western Virginia, and Ohio.

In the following table the various iron-mining States are arranged in the order of their production.

PRODUCTION OF IRON ORE IN THE UNITED STATES DURING THE YEAR 1879-1880.[1]

	Name of State.	Number of Counties Reporting.	Number of Establishments.	Total product. Tons of 2,000 lbs.	Value of Product.	Total Number of Employés.
					$	
1	Pennsylvania . .	34	358	2,185,675	5,517,079	8,733
2	Michigan	2	43	1,834,712	6,034,648	5,562
3	New York	12	78	1,262,127	3,654,422	4,675
4	New Jersey . . .	6	109	757,372	2,910,442	4,811
5	Ohio	8	30	547,303	1,269,530	1,716
6	Missouri	8	48	386,197	1,674,875	1,893
7	Alabama	10	17	191,676	201,865	738
8	Virginia	9	26	182,326	439,886	939
9	Maryland	5	13	139,628	421,691	329
10	Tennessee	12	34	104,465	147,181	552
11	Georgia	3	7	91,416	143,622	342
12	Kentucky	4	5	64,809	165,905	325
13	Massachusetts . .	1	9	62,637	226,130	382
14	West Virginia . .	6	8	61,216	101,557	266
15	Wisconsin	2	2	41,440	73,000	62
16	Connecticut . . .	1	4	35,018	147,799	200
17	Oregon	1	1	6,972	4,669	14
18	Maine	1	1	6,000	9,000	20
19	Texas	1	—	3,600	8,100	—
20	North Carolina .	6	9	3,318	5,285	47
21	Delaware	1	2	2,726	6,553	47
22	Vermont	1	1	560	2,750	15
23	Indiana	1	—	513	1,018	—
	Totals . . .	135	805	7,971,706	23,168,007	31,668

A small amount of ore raised in Colorado is omitted, as it is used as a flux, and does not, as yet, affect the iron manufacturing industry. In several of the States, especially Texas and Indiana, soft ores are

[1] *Census Bulletin*, No. 270.

obtained from surface diggings. These are raised by farmers, during the intervals of agricultural employment, and the product drawn by farm teams to the nearest furnace and sold.

General Summary of the Production of Metals, &c., in the United States during the Year 1882.

Metal or Ore.	Quantity.	Value.	
		$	£
Pig Iron	4,623,323 tons	106,336,429	21,267,286
Gold	1,572,186 oz.	32,500,000	6,500,000
Silver	36,197,695 „	46,800,000	9,360,000
Copper	45,823 tons	16,038,091	3,207,618
Lead	132,890 „	12,624,550	2,524,910
Zinc	33,765 „	3,646,620	729,324
Quicksilver	4,033,998 lbs.	1,487,537	297,507
Nickel	140 tons	309,777	61,955
Cobalt	—	15,000	3,000
Antimony	60 „	12,000	2,450
Manganese ore	3,500 „	52,500	10,500
Chrome iron ore	2,500 „	100,000	20,000
Total value of Metals, &c., produced in 1882		219,922,504	43,984,550

The above table has been compiled from a report[1] by Mr. A. Williams, of the U.S. Geological Survey. In most cases the number of tons of ore mined is not given, but it is stated that 9,000,000 tons of iron ore, worth $32,400,000 were obtained during the year.

DOMINION OF CANADA, &c.

Canada.

The principal metallic and metalliferous productions of Canada are gold and silver, with copper and iron ores; but various other minerals, such as iron pyrites, blende and galena, likewise occur in considerable quantities, as does also apatite, which is mined for the manufacture of artificial manures. Although, however, these minerals sometimes occur in comparatively large quantities, Canada can scarcely be regarded as a metalliferous country of exceptional richness.

[1] "The Mineral Resources of the United States," Washington, 1883.

GOLD.—The existence of gold in the sands of the Chaudière Valley was first made known in the year 1835 by Lieutenant Baddeley, R.E., and since that period repeated examinations have shown that this metal is by no means confined to the district in question, but that it exists in the superficial deposits of a wide region on the south side of the St. Lawrence, extending from the St. Francis to the Etchemin Rivers, and from the first line of hills on the north-west to the limits of the province on the south-east. The original source of the gold would appear to be the crystallized schists of the Notre Dame Range; the materials derived from the disintegration of these rocks not only constituting the superficial material among the hills of this range, but also spreading over a considerable area to the south of them. The same gold-bearing rocks may be traced in a south-westerly direction, along the great Appalachian Chain, to the Southern United States. Gold has also been found in Canada associated with galena, blende, and pyrites, enclosed in well-defined quartz veins intersecting slates which are believed to be of Silurian age. At Nutbrown's Shaft, situated in the township of Leeds, masses of gold, each weighing several dwt., were found associated with copper glance and specular iron ore, in a vein mainly consisting of a ferruginous bitter spar; small scales of the same metal have also been found in the enclosing country rock. The rocks of this locality belong to the Quebec group, but the precious metal has rarely been found in place, and in Canada the working for it has been almost entirely confined to various superficial deposits of clay, sand, and gravel.

Gold is found very generally disseminated throughout the alluvial deposits of the region of which the limits have been above roughly defined, and is not restricted to the river beds, as the forces which distributed the auriferous gravels were evidently anterior to the formation of the present water-courses of the country. When the lighter portions of the gold-bearing gravels have been removed by washing, the residue is found to contain a large quantity of black ferruginous sand consisting of a mixture of magnetite, ilmenite, chromite, and hæmatite, with occasional small crystals of garnet, rutile, and zircon. The grains of gold are sometimes angular, but are more frequently much water-worn, and vary in size from nuggets weighing several ounces to the finest dust-like scales.

Gold has been found in the St. Francis River from the vicinity of Melbourne to Sherbrooke, in the townships of Westbury, Weedon, and Dudswell, and on Lake St. Francis. It has also been discovered on the Etchemin, and on the Chaudière and nearly all its tributaries, from the seigniory of St. Mary to the frontier of the State of Maine, including the Bras, the Guillaume, the Rivière des Plantes, the Famine, the Du Loup, and the Metgermet. Several attempts to work auriferous alluvial deposits have been made in the seigniories of Vaudreuil, Aubert-Gallion, and Aubert de l'Isle, but have all been successively abandoned. The country people, however, still attempt, from time to time, the washing of the gravel, generally by means of a pan, and are occasionally rewarded by the discovery either of a little coarse gold or of a small nugget. In the years 1851 to 1852 an experimental gold-washing on a somewhat considerable scale was carried out on the Rivière du Loup, near its junction with the Chaudière. The system of washing adopted closely resembled that employed in Cornwall for tin-streaming, but during the summer months the supply of water was occasionally very limited. In this way about three-eighths of an acre were washed away yielding 105 oz. 7 dwt. of gold, of which eight ounces were in the form of fine dust mixed with about a ton of black iron sand, the residue of the washings. Several nuggets weighing over an ounce were obtained, and the total value of the gold collected was $1,829, while the expenditure amounted to only $1,143, leaving a gross profit of $686.

In 1852 about five-eighths of an acre of gravel were washed near this locality, and the total amount of gold obtained was 144 oz., valued at $2,496. Of this quantity 15 oz. 7 dwt. were in the form of dust mixed with iron sand, while another portion was in the form of nuggets. Nine of the largest of these weighed, together, 23 oz. 8 dwt.; of these the smallest weighed 11 dwt., and the largest 6 oz. 7 dwt. A little platinum and iridosmine were also obtained, but the quantity of these was small. The profit resulting from this operation amounted to $608, but a portion of the expenditure was for the construction of a wooden flume for bringing water from a distance of about 900 feet. As these would be available for several successive years, a proper allowance made for them would increase the profit to about $680. It consequently appears that from an acre of gravel having an average thickness of two feet there was taken gold of the value of $4,323, while the cost of labour, after deducting all expenses not directly incurred in gold-washing, was $2,957, leaving a gross profit of $1,366. The fineness of the gold-dust obtained was 871.[1]

The rocks upon which the gold-bearing gravels of Lower

[1] *Geological Survey of Canada: Report of Progress*, p. 741, Montreal, 1863.

Canada usually repose contain various reefs or bands of quartz, which generally follow the direction of their stratification, namely, north-east and south-west.

Although these veins present numerous outcrops, both they and their enclosing rocks are more frequently concealed by a covering either of vegetable soil or of superficial drift. These veins would appear to be most plentiful in the slates and sandstones of the Quebec group, but their thickness and aspect are extremely variable. The quartz is generally white, but is sometimes coloured by oxide of iron resulting from the decomposition of pyrites, which often leaves cavities, imparting to the mass a somewhat cavernous structure. Some of these veins are, on the one hand, composed almost entirely of quartz, while others, on the other, contain various metallic sulphides, such as iron pyrites, chalcopyrite, galena, blende, &c. with frequently a little gold. The auriferous quartz veins of Lower Canada exhibit no unusual features, and it is believed that at the present time none of them are being worked for gold.

Mr. A. Michel, who reported in 1866 upon the gold-fields of Lower Canada, states that the acquisition by American companies of a great part of the auriferous lands along the borders of the rivers Chaudière, Famine, Du Loup, and their numerous tributaries, as well as the sale made by the Messrs. De Léry to another company of the mining rights of the seigniory of Vaudreuil (Beauce), might have been expected to have given an impulse to the working for gold in this district. Such however had not been the case, none of the companies, since their organisation, having undertaken any serious explorations of their properties, while at the same time the country people had abandoned their search for alluvial gold, and the influx of strangers (who came there for the same purpose in great numbers in 1864) had entirely ceased in 1865.[1]

A belt of gold-bearing quartz veins is stated to occur thirty miles north of Belville, in the township of Marmora, Ontario. These reefs are, for the most part, conformable with the stratification, and contain gold in association with various arsenical sulphides. The Huronian slates which extend a considerable distance north-west of the head of Lake Shabendowan, are of special interest as containing numerous veins, of which some are auriferous. A large number of these veins has been discovered, all of which have an east-north-east direction in conformity with the strike of the beds. The veinstone consists uniformly of quartz,

[1] *Geological Survey of Canada: Report of Progress*, p. 49, Ottawa, 1866.

containing copper pyrites, in which the gold when present is enclosed, or it is disseminated through the quartz in such a state of fine division that its particles cannot be detected by the aid of a hand lens.[1]

Gold mining is not, however, carried on with any degree of activity in Canada proper, and the annual production of gold is not considerable.

SILVER.—The rocks which immediately surround Thunder Bay, on the north shore of Lake Superior, belong to the so-called "Lower" and "Upper Copper-bearing Series" of Canadian geologists. The relations existing between these two groups have not been satisfactorily determined, and the age of both is still a matter of opinion.

The Upper Copper-bearing Series consists essentially of dolomitic sandstones, reddish limestones, indurated red and yellowish marls, red sandstones, and conglomerates with interstratified traps. They have generally been regarded as corresponding either to the Potsdam Sandstone or to some of the lowest members of the Lower Silurian formation, but Mr. R. Bell, of the Geological Survey of Canada, some years since put forward the opinion that they are really of Triassic or Permian age. This view of the question is not, however, generally accepted.

The Lower Copper-bearing Series is well exposed on the north shore of Thunder Bay, and extends beyond its limits as far westward as the mouth of Pigeon River. The series consists, in ascending order, of:—(1) green siliceous conglomerates containing pebbles of quartz, jasper, and slate; (2) grey and black chert-bands separated from one another by thin courses of dark grey dolomite; (3) black shales and flags with associated hornblende traps; (4) grey argillaceous sandstones and shales. No organic remains have been discovered in any member of the Lower Copper-bearing Series of Thunder Bay. Its entire thickness is probably about 1,500 feet, and the general strike of the rocks varies from, approximately, east and west to about north-east and south-west. The whole series is traversed by dykes of trap, and there are several interstratified beds of that rock.

The Lower Copper-bearing Series is penetrated by numerous mineral veins, of which the majority run along the strike of the beds, having a general east-north-east and west-south-west direction; but there is also a set of transverse lodes of which the

[1] H. Alleyne Nicholson, "On the Geology of the Thunder-Bay and Shabendowan Mining Districts," *Quart. Jour. Geol. Soc.*, vol. xxix. 1878, p. 16.

direction approaches more nearly to north and south. One of the most important of the series of veins which follow the strike of the stratified rocks and have a general east and west direction, is the Shuniah Vein, which has been worked upon at several points along its course. It is enclosed in the Lower Copper-bearing rocks of the north shore of Thunder Bay, running nearly parallel to the shore, and at a distance inland of from one and a half to two miles. At the Shuniah Mine itself, the vein courses nearly east and west, and is almost vertical; its width is about twenty-two feet, and the veinstone mainly consists of calcite. Quartz and fluor spar are, however, occasionally present, and iron pyrites often occurs in considerable abundance. Silver is present both in the native form and as sulphides, some specimens being extremely rich. This vein is enclosed in hard black shales, but a large mass of hornblendic trap lies about fifty feet to the south; the lode does not, however, exactly conform to the strike of the beds, so that in following it westward a point is reached where the trap forms the foot wall of the vein. Like the majority of the lodes on the north shore of Lake Superior, the Shuniah Vein is of a brecciated character and contains numerous fragments of the country rock. At all points, where it has been opened upon, this vein has been found to contain silver either in the metallic state or in the form of argentite.

Of all the silver-bearing lodes worked in this region the most important is perhaps the Silver Islet Vein, situated on a small rocky island immediately south of Thunder Cape. Silver Islet is three-quarters of a mile from the mainland, and is much exposed to storms from the west, south-west, and east. The island measured originally about ninety feet each way, and rose only eight feet, at its highest part, above the level of Lake Superior. The whole of the rock is now enclosed, and is either covered by works and buildings connected with the mine or by newly made ground. The course of the vein is about N. 35° W., and its dip 85° towards the south-east. Its greatest width is on the north-western side of the islet, where, as is seen in Fig. 93, it divides into two branches, one of which crosses the islet while the other keeps on the western side of it under water. The southern part of the latter branch has always carried the richest ore, the northern branch being less rich, while the whole of the vein to the westward is almost entirely barren, consisting mainly of large masses of calc spar, with a little quartz and a few cubes of galena containing mere traces of silver. Particles of silver ore are frequently found in small feeders in the country rock between the two branches of the vein, and fragments of the same rock, associated with graphite, are often enclosed in the veinstone.

The metalliferous minerals contained in the veins are native silver, silver glance, tetrahedrite, domeykite, galena, and blende, with iron and copper pyrites, and small quantities of the ores of cobalt and nickel. One of the rocks intersected by the vein is a diorite in the form of a dyke, which differs in some respects from the other eruptive rocks of the district. The silver vein is a true lode, cutting through the horizontally bedded schists as well as the dyke of diorite, which, although an eruptive rock, has not in any way tilted the schists on edge. The deepest workings are 1,160

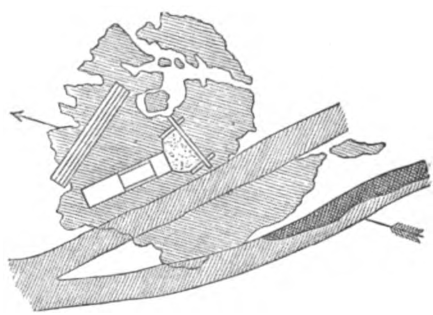

FIG. 93.—Silver Islet; plan.

feet below the surface, and the longest drift on the course of the vein is 1,250 feet in extent.

The fissure in which this vein has been formed is also a line of fault, which has moved the rocks as shown in Fig. 94, which indicates roughly the positions of the rocks and lode below the "5th level." The most productive portion of the vein is marked in Fig. 93 by cross-hatching, and it is worthy of notice that the rocks intersected by the diorite are not highly inclined crystalline slates, but unaltered and almost horizontal flagstones and shales. From the date of its first discovery, in July 1868, to the end of December 1882, this vein had yielded silver to the value of three and a quarter million dollars, or above £650,000.

The Silver Islet Vein has, on one occasion, exhibited a phenomenon which is worthy of notice, and which has been described by Mr. Frue, who was local superintendent at the time of its occurrence. On December 28th, 1875, while a party of miners were engaged in drilling a hole in the end of the drift at the "8th level," the drill broke suddenly into a crevice. Water at once commenced to flow, but not in any large quantity, and, not being aware that it was accompanied by an escape of gas, one of the miners took a candle to look at the hole. The gas instantly took fire, sending out a flame of many feet in length, the miners having to throw themselves on the bottom of the level to escape injury, and there remain until the flame had subsided. After having somewhat got over their astonishment they returned to the drift, and when still at a distance of several

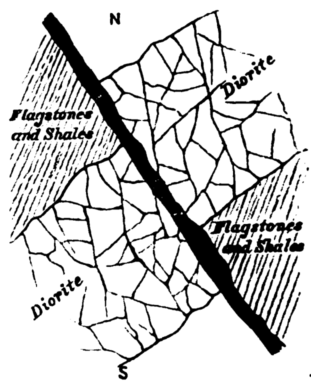

FIG. 94.—Fault, Silver Islet.

feet from the end the gas again ignited. They afterwards walked into the level without a light and stopped the hole with a wooden plug. On subsequently applying a lighted candle to the imperfectly plugged hole, however, the gas again took fire, giving a jet of flame about a foot in length, which burned for several weeks.[1]

Native silver occurs in small quantities in several other localities on Lake Superior, as at St. Ignace Island, Spar Island, and Michipicoten Island; the copper ores of the Eastern Townships are likewise often to some extent argentiferous, and galena containing silver is found in various parts of Canada. No lead mines have hitherto been successfully worked in Canada, and the proportion of silver present in the ores is not often large.

[1] Thomas Macfarlane, "Silver Islet," *Trans. Amer. Inst. Mining Engineers*, vol. viii. 1880, p. 226.

COPPER.—The copper ores of the Quebec group of Lower Canada occur chiefly as interstratified beds, and are often found in the limestones of this series. These limestones are generally magnesian, and are frequently associated with serpentines and diorites, both of which occasionally contain copper. These rocks are accompanied by slates which in many places are themselves the copper-bearing strata; but they are sometimes so altered as to take the form of chloritic or micaceous schists. The latter are in some cases soft, with a pearly lustre, and are then known as nacreous slates. At other times these rocks are highly siliceous, so that it not unfrequently happens that the copper-bearing bed presents the appearance of a micaceous quartzite. Beds of talcose slate and steatite likewise occasionally contain copper, which is also sometimes found in the red and green argillites of the series. The chloritic schist occasionally becomes calcareous, and gradually passes into an impure limestone. The metal occurs throughout these rocks in the form of erubescite, chalcocite, and copper pyrites. Malachite, azurite, and cuprite are met with in small quantities, but only near the surface.

Native copper, so abundant in the rocks on the southern shore of Lake Superior, is seldom met with in Eastern Canada; it, however, sometimes occurs in small quantities in certain red slates. At St. Flavien it is found associated with calcite in an amygdaloidal rock, under conditions closely resembling those which obtain in more western regions. In many parts of the district the copper-bearing beds are traversed by veins which, in some cases, do not contain any metalliferous mineral. Sometimes, on the contrary, they carry large quantities of rich ores, and molybdenite, spathose iron ore, and gold have also been found in these veins. They are seldom continuous for any considerable distance, and the most persistent source of copper ores in this region has been the metalliferous beds. In some cases, as in Sutton and Melbourne, the copper ore occurs in certain beds of dark-coloured slates in a state of such fine division as to be only visible upon close inspection, although the rock may contain from 5 to 10 per cent. of copper. In the magnesian limestones a schistose structure is sometimes observable, and the copper ore is occasionally distributed through them in the same way as it is in the slates. They are, however, more frequently massive, and the ore often occurs in nodules or as grains irregularly disseminated throughout the rock. In these limestones, as well as in the more schistose strata, there are veins in which the ores of copper are concentrated in a gangue of bitter spar, calcite, or quartz. Sometimes, as at the Acton Mine, ores of copper form the cement of a limestone conglomerate.

In Leeds the copper-bearing rocks are exposed in a greater number of places, and have been more carefully examined, than in any other locality. The explorations at the Harvey Hill Mine are the most extensive which have been made in the Eastern Townships, and have resulted in opening out some very interesting deposits. The copper ores of this locality occur both in veins and in beds; the strata, for the most part, consisting of fine-grained micaceous schists, which from their unctuosity are frequently called talcose, although they are not usually magnesian. A bed of steatite forms, however, one of the members of the series, and bands of a dark kind of argillite are sometimes met with; while other beds, either white or light grey in colour, contain nodules of chloritoid and, less frequently, crystals of schorl. The dip of the strata is from N. 10° to 65° W., with an inclination varying from 15° to 30°. The lodes are irregular lenticular veins, which do not coincide with the strata either in dip or in direction. They generally run about 20° E. of N., although the course of a few of them is more nearly east. Their dip, at varying angles, is usually towards the west. Some of these veins, which appear to have filled fissures in the slates, have been traced on the surface for a distance of 100 fathoms. They are occasionally, in their thickest parts, from six to seven feet in width, but gradually thin out both horizontally and in depth. These veins, of which the gangue is principally quartz, more or less mixed with calcite, pearl spar, and chlorite, often contain very rich ores of copper, some of them yielding erubescite, or chalcocite, or both, while others afford copper pyrites only. Within an area of about thirty acres open cuttings were made upon as many as fifteen distinct lodes, and shafts were sunk upon two others. Notwithstanding that these lodes were sometimes found exceedingly rich, the distribution of copper in them was so uncertain that they were regarded as secondary in importance to the interstratified beds, in which ores of copper are disseminated in the slaty rock. The first of these beds, three in number, varies in thickness from two to six feet, and was found on sinking near the summit of the hill at a depth of fifteen fathoms below the surface. Beneath this are some fathoms of barren slates, and then a thin layer of cupriferous rock resting upon a bed of steatite. Another ore bed was subsequently struck at a still greater depth of about twenty fathoms. From the uppermost bed a considerable amount of ore was extracted through Kent's Shaft, at about twenty fathoms from the surface. The second bed, that lying upon the soapstone, should be sixty fathoms from the surface at this point, while the lowest will be still deeper by about twenty fathoms, or will have a depth of eighty fathoms from the surface at Kent's Shaft. The copper ores are disseminated through these slates in small masses, often of a lenticular form, running parallel to the bedding of the rocks.

In the accompanying section, Fig. 95, of the Harvey Hill Mine, *a*, *b*, and *c* represent the three cupriferous beds, *d*, quartz veins or lodes, and *e*, Kent's Shaft with its various cross-cuts.[1]

In stoping to the west of Kent's Shaft an unusual phenomenon attracted attention, and was at first ascribed to the presence of an ordinary bunch of ore. This is described by Mr. J. Douglas, jun., as having first broken through the floor of the bed and appearing as though it had discharged its cupreous solutions into the lowest layers of the slates. As it was followed in stoping, it worked its

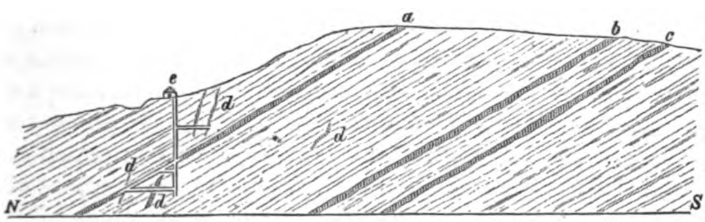

FIG. 95.—Harvey Hill; transverse section.

way up through the slates, and assumed the features of a lode with well-defined walls, terminating in the bed, into which it appeared to have poured its contents. The course of the copper ore, bitter spar, and calc spar, as they penetrated from the lode among the slates, could be readily traced, and Mr. Douglas is of opinion that the bed had derived its metalliferous constituents from the veins. He adds that subsequent observations tended to strengthen this opinion.[2] The observations of Mr. Douglas, and the conclusions to which he has arrived, are of great interest, and are worthy of due consideration; but, after having, on two occasions, spent several days at Harvey Hill, I am inclined to believe that the various phenomena described may be equally well accounted for upon the hypothesis that the copper ores of the veins were derived from the stratified beds.

[1] *Geol. Survey of Canada: Report of Progress*, p. 727, Montreal, 1863.
[2] James Douglas, jun., "Notes on the Copper Deposits at Harvey Hill," *Trans. Lit. Soc. of Quebec*, 1871.

Some of the broken ground, consisting of alternate layers of quartz and slate, carries rich bunches of ore, and in some of these masses are found chloritoid, molybdenite, and quartz crystals with their angles rounded off as though they had been exposed to the action of a solvent. Specimens of erubescite from this locality are sometimes thickly studded with such crystals, some of them being several inches in length and above an inch in diameter, with their angles almost effaced and their faces dimmed. Although continuously worked during several consecutive years, the copper veins and cupriferous beds of Harvey Hill entirely failed to yield remunerative results, and as a consequence the workings have long since been abandoned.

At the Acton Mine, limestone is seen dipping to the north-west, the hill south-east of the workings being composed of the massive beds making up the lower portion of the formation. The Copper-bearing Limestone overlies this, and occurs in irregular elongated masses running parallel to the great body of limestone beneath, but varying from it both in thickness and in structure. The upper limestone at this mine is underlain by shales, which often contain more or less copper ore, and are also sometimes to a small extent interstratified with the limestone. With these shales occur beds and masses of diorite which weather to a brownish-yellow colour, in that respect resembling many of the serpentines of the district. Some of the masses of diorite seen in the Acton Mine are 150 feet in length by 50 feet in thickness, but thin beds of the same rock are occasionally interstratified with the slates. In some portions of the diorite masses of calcite are disseminated, thus giving to it the character of an amygdaloid, and imparting a cellular aspect to the weathered surfaces. At other times the copper-producing rock would appear to be a conglomerate containing small pebbles, the longer axes of which lie in the direction of the bedding. Diorites similar in character to those of Acton, and occupying the same stratigraphical position, occur with the Copper-bearing Limestones at Upton, Wickham, Somerset, Nelson, and St. Flavien, and the fact that at the latter place, as well as at Drummondville, they contain copper ores gives to these rocks considerable economic importance.

Portions of a cupriferous slate are sometimes interlaminated with the beds at the base of the limestone, as well as with the underlying diorite. Several dislocations, although none of them of any considerable magnitude, occur at this locality. Some of these appear to follow the strike of the bedding, while others occur in two groups of nearly parallel faults, each of which is oblique to the other, as well as to the strata. These dislocations disturb the continuity of the Copper-bearing Limestone, causing the diorite, and even the upper portions of the limestone, to protrude into or to interrupt the ore-bearing beds. The underlying limestone is often intersected by quartz veins, which occasionally contain spots of galena or copper pyrites. The workable copper ore is chiefly found in the conglomerate above mentioned, of which it sometimes constitutes the cement; it also occurs in portions of the limestone in the immediate vicinity of, or partly surrounding, the conglomerate. Short irregular veins, containing calcite and sulphides of copper, sometimes enclose a black graphitic substance.

The most important masses of ore occurred in the form of three large bodies, extending over a length of about 120 fathoms, and may have originally belonged to one continuous stratum subsequently divided by dislocations. Of these masses the most northerly, which began with a depth of a few inches, gradually extended to a horizontal distance of forty fathoms with a thickness of forty-five feet. Upon this an open cutting was made to a depth of twenty feet, at which point the limestone had become reduced to a thickness of only four feet. In the north-eastern part of the open working referred to, a shaft was sunk upon the dip of the limestone to a depth of about ninety feet from the surface, where the bed was twenty-four feet in thickness, but poor in copper. At a depth of sixty feet a level was driven about thirty feet westward, where the limestone, which was there sixteen feet in thickness, was cut off by the overlying shale. The ores from this and from the other two deposits were extracted by means of irregular workings, but in the aggregate yielded a large amount of rich copper ores of exceptionally good quality. From the three masses at the Acton Mine,[1] 16,300 tons of 12 per cent. ore were obtained and sent to market; but in the year 1866 all the available deposits had become exhausted, and no exploratory work for the discovery of others having been executed the mine was abandoned.

The distribution of copper throughout the rocks of the Quebec group is very general, and, according to Sir W. E. Logan, would appear to indicate that this metal was almost everywhere present in the waters from which these strata were deposited.[2]

The copper-bearing veins which traverse the Huronian rocks on

[1] *Geol. Survey of Canada: Report of Progress*, p. 209, Ottawa, 1866.
[2] *Ibid.* 1863, p. 515.

the north side of Lake Huron, at the Bruce Mines, and several adjacent localities, contain, in a gangue of quartz, copper pyrites with, near the surface, chalcocite and erubescite, which are generally massive but in some cases crystalline. Heavy spar, calcite, and pearl spar are also occasionally present. The two lodes which have been worked vary from two to four feet in width, and the proportion of ore in them, as compared with the other vein-stuff, was at one time very large. The total quantity of ore obtained from this mine, from the date of its commencement in 1847 to the beginning of 1863, was about 9,400 tons averaging 18 per cent. of copper.

To the north-west of the Bruce Mines are the Wellington Mines, in which the veins closely resemble those of the Bruce, of which they are probably a continuation. The same veins extend into the adjoining property known as Huron Copper Bay. These veins, which were worked for many years with varying success, appear to have become impoverished in depth, and the mines have now for some years been abandoned.

The Wallace Mine is situated on the shore of Lake Huron, about a mile west of the mouth of White Fish River, on the north side of the bay. The strata here consist of quartzose and chloritic slates dipping northward at a high angle, and include a large mass of greenstone running with the strike of the rocks. Strings and bunches of copper pyrites occur in this locality, both interlaminated with the schists and disseminated in the greenstone. At a distance of a mile and a half further east, and near the base of the hills, two large veins containing iron pyrites with a little yellow ore are said to occur.

On the north side of the island of Michipicoten is a cliff from two to three hundred feet in height in which the greenstone is marked by druses containing analcime and quartz. A soft amygdaloidal bed containing native copper is traceable for some miles along the shore, sometimes beneath the surface of the water in the bays, and at others running a short distance inland. In this bed an attempt was, a few years since, made to work a remarkable deposit of native copper and silver disseminated in grains through hydrous silicate of nickel. The ore was first stamped, and the nickel ore, the value of which was not suspected, was washed away, leaving a metallic residue consisting of a mixture of native copper and native silver. After fusion this residuum yielded an alloy of copper and silver, in which the latter metal was, in one instance, present to the extent of nearly 12 per cent. A shaft was sunk to a depth of about twelve fathoms, but after a considerable outlay the workings were ultimately abandoned. Very little is known relative to the mode of occurrence of this singular deposit, which is said to be associated with calcite.

IRON.—The iron ores of Canada possessing economic importance are magnetite, red hæmatite and limonite. Spathose iron ore has not been observed to occur in any considerable quantities. The most abundant iron ore of the province is probably magnetite, which is found only in crystalline and metamorphic rocks. It occurs in the Laurentian series, and in the rocks of the eastern Palæozoic basin. A description of the principal deposits of this ore would occupy much more space than can be devoted to the subject, and, consequently, a few only of the more remarkable will be mentioned.

At Grenville a bed of iron ore, from six to eight yards across, occurs in a gneiss which is interstratified with numerous bands of quartzite. It has been traced for a distance of about 350 yards on its strike, the accompanying beds being cut off at either end by a mass of intrusive syenite. A large deposit of magnetic iron ore likewise occurs in the township of Hull, and is said to have been again met with at a distance of about a mile on the other side of the hill. The ore is found in syenitic gneiss interstratified with a white crystalline limestone containing mica and graphite, and forms a bed about ninety feet in thickness. This appears to have been brought to the surface on the crown of an anticlinal curve, through which appears an underlying bed of crystalline limestone. The ore is coarsely granular and very pure, but is in some places associated with scales of graphite. In the year 1854 this deposit was opened, and was worked for about four years for the purpose of supplying certain furnaces at Pittsburg, Pennsylvania; but in 1858 the workings were suspended on account of the discovery of the Newborough Mine, which is more conveniently situated for the transport of ores.

An important deposit of magnetic iron ore occurs on an island in Mud Lake, on the Rideau Canal, near Newborough. It forms a bed 200 feet in thickness, running north-east and south-west in gneiss adjoining a crystalline limestone.

At South Sherbrooke a bed twelve feet thick of magnetic iron ore occurs in gneiss, and in the vicinity of Madoc there is another bed from which ore was formerly brought to that village, where it was smelted in a blast furnace and yielded iron of excellent quality. This bed appears to be enclosed in a soft black micaceous rock, and to follow a course somewhat south of east. The greatest thickness of this deposit is thirty feet, but it would probably average about twenty feet.

The magnetite formerly smelted at Marmora was obtained from Belmont, and the deposit, which is generally known as the Big Ore Bed, is commonly said to be 100 feet in thickness. It is not, however, a single bed, but a succession of beds of ore interstratified with layers of talcose schist and crystalline limestone, with which are associated serpentine, chlorite, diallage, and a greenish epidotic rock.

Red hæmatite not unfrequently replaces magnetite in rocks of the Laurentian series, and an important deposit of this ore occurs in the township of McNab. The bed of ore, which is thirty feet thick, rests upon crystalline Laurentian limestone, and is overlain by a magnesian limestone of Lower Silurian age. To the westward this bed has been traced for a distance of about a hundred yards, but in the opposite direction it is concealed by a marsh. The ore is usually compact and has a purple tint, but occasionally it exhibits a finely crystalline structure. Its yield of metallic iron is usually about 59 per cent.

The red hæmatite ores of the altered strata belonging to the Quebec group, are generally composed of small crystalline scales of the micaceous variety of the red oxide of iron associated with grains of quartz, and occasionally with chlorite. These foreign minerals are present in very variable proportions, so that the schists are sometimes a rich iron ore, while at others they are so poor as to possess no commercial value. Several exposures of these iron slates occur in the township of Sutton, and the same ferruginous rocks are again met with in the adjoining township of Brome. A bed of iron slate, two feet in thickness, is said to occur in chloritic schist in Inverness, and it is probable that these ores which are so abundant in the townships of Brome and Sutton will be found in many intermediate localities. These slaty iron ores, although generally less rich than those of the Laurentian series, are frequently sufficiently so to admit of their being smelted with advantage.

The more solid varieties of limonite have not hitherto been met with in Canada, but bog iron ore of recent formation is found near the surface of the soil, and is widely diffused throughout the country. On the shore of Lake Erie this ore is found in various localities, especially in the townships of Charlotteville, Middleton, and Windham. In the seigniory of Vaudreuil, at Côte St. Charles, there is a deposit of bog iron ore which has been traced over an area of about three acres, and which probably extends much further. This bed of ore varies from four to eight feet in thickness. Bog iron ore is also found at Côte St. Louis, at Côte St. Guillaume in the adjoining seigniory of Rigaud, and in numerous other localities. In the Eastern Townships bog ore occurs in considerable abundance in Stanbridge, and is also met with in the adjoining township of Farnham. The ore from Stanbridge was formerly mined and carried to Alburg in Vermont, where it was smelted. This ore occurs in the seigniory of St. Vallier, and is found in abundance on Green Island. The St. Maurice forges, in the vicinity of Three Rivers, were for more than a century supplied with bog ore collected in that vicinity, and between the St. Maurice and Batiscan Rivers some important deposits of this ore have been met with. In the vicinity of the village of Industry there are extensive deposits of bog ores, as well as at Batiscan in the seigniory of Cap de la Madeleine.

Although never directly employed as an iron ore, iron pyrites is made use of as a source of sulphur, and is consequently a mineral of much importance in the manufacture of sulphuric acid. Iron pyrites occurs in large quantities in various parts of Canada, and is sometimes associated with small quantities of yellow copper ore. A large deposit of pyrites occurring at Elizabethtown, near Brockville, appears to be an interstratified mass, and has, in some places, a thickness exceeding thirty feet. In addition to copper this mineral contains traces of cobalt. An important bed of cupriferous iron pyrites occurs at Garthby, and another at Ascot.

NOVA SCOTIA.

GOLD.—Palæozoic rocks extend along the whole of the Atlantic seabord of Nova Scotia from Seaterie to Cape Sable, while the planes of stratification, which have a general east and west course, are generally parallel with the coast line and with the various axes of upheaval. The leads, or veins, of auriferous quartz, with comparatively few exceptions, conform with the strike of the slates and quartzites, following every plication of the strata and giving rise to an idea, formerly entertained by certain geologists, that they were contemporaneous beds and not subsequently-formed veins. The quartz veins are, however, by no means confined to the districts in which gold has been found in paying quantities, but those which have proved to be auriferous are usually in the vicinity of the axes of anticlinal folds. On the top of Laidlaw's Hill, in the Waverley district, the lead lies so flat that it is worked long wall, the gold being found chiefly where the quartz has been crumpled together by the folding of the strata so as to form the rolls locally known as *barrels*. These corrugations, which have been followed down on both the northern and southern dips of the vein, on the crest follow the direction of the axis of the anticlinal, while the plication of the quartz is marked in the overlying stratum by very moderate undulations only.

The exact horizon of the auriferous rocks of Nova Scotia has yet to be determined, but it has been suggested by those who regard the leads as being bedded deposits that only the lowest rocks of the series contain gold leads, and that these have been brought to the surface by anticlinal folds. Mr. Poole is, however, of opinion that the lithological characteristics of the several districts point to the existence of three distinct groups enclosing auriferous leads, namely:—1. The lowest composed of much decomposed and contorted slates and grits cleaving transversely to the planes of bedding. 2. The middle compact beds, in which quartzite predominates, and of which the cleavage usually conforms to the planes of deposition: numerous quartz leads, some of which are appreciably auriferous, are intercalated with the rocks of this group in the neighbourhood of anticlinals. 3. The upper group, in the extreme western section of the province, consists of fissile slates of an olive-green colour associated with micaceous sandstones, and with at least one bed containing graphite.[1]

In some of the strata chlorite is abundant, but in the principal gold districts this mineral is by no means of frequent occurrence. Mr. Selwyn, Director of the Geological Survey of Canada, states that some of these sandstones contain pebbles of grey quartzite, and is inclined to believe that they will be found to occupy the position of some division of the Quebec group. Mr. Poole calls attention to the fact that there can be no doubt with regard to the relative age of the gold-bearing veins associated with rocks belonging to this section, since at Gegoggan and Cranberry Head there are veins which, when exposed at low water, are seen to course across the strata and occasionally swell out into masses of from six to eight feet in width: these, within a few feet, contract to so many inches, and again expand and contract. Similar veins have been found to

[1] Henry S. Poole, "The Gold Leads of Nova Scotia," *Quart. Jour. Geol. Soc.* vol. xxxvi. 1880, p. 307.

contain gold, and in some instances they have yielded as much as an ounce of gold per ton of quartz.

In Nova Scotia mining operations have not been exclusively confined to the apparently "bedded leads," as rich quartz has been obtained both from "cross-leads" and the so-called "angling leads." Angling leads are true veins, although generally very small; they have usually an east and west course, and cross the strata at small angles. In depth they gradually steal across the beds of slate, but on meeting with quartzite break directly through it to the next stratum of slate and continue to do so in depth. In nearly all cases angling leads are found most productive where passing through quartzite. True cross-leads are of later age than the interstratified beds, and are almost always barren; but in addition to these there are bands of quartz connecting parallel leads, as well as offshoots, which are often called cross-leads, and these are sometimes auriferous. The paying leads are generally small, one eight inches in width being regarded as of good size; thicker ones are, however, sometimes worked.

In mining the regular bedded leads, phenomena characteristic of metalliferous veins are frequently observed. The workings on the Union Lead at Waverley, a lead which has been frequently referred to as affording evidence of the bedded origin of these veins, have shown that although the quartz ceases at a certain point the vein fissure nevertheless continues its regular course. In one of the stopes at the same place the quartz formed a roll eight feet in width, and threw off numerous branches into the foot wall. Another characteristic, which may be regarded as affording evidence of the vein-like origin of these beds, is, that they sometimes taper out and are continued by splices starting on one side or the other in the wall rock. The most unmistakable evidence of their vein-like origin is, however, afforded by the occasional presence of horses of the rock forming their hanging wall. An example of this occurred in the Barton Lead at Tangier, where a flake of slate ten feet in length was found embedded in the middle of the quartz. This flake had rough edges, and had evidently become detached from a depression in the hanging wall, its course from which was distinctly marked by a series of slaty fragments embedded in the quartz at each end. Fragments of slate are often found in these leads, and in some places laminæ of slate impart to them a ribbon-like structure, suggesting a series of openings of the vein fissure and successive deposits of quartz.

A Carboniferous conglomerate is, in a small way, worked at Gray's River for the gold which is mixed with the lower portions of the bed and in the runs or hollows in the slate; the bed-rock is also sometimes removed to a depth of from three to four feet for the gold contained in the backs or crevices between the planes of cleavage.

Although of considerable interest to the geologist, the gold mines of Nova Scotia are not commercially of great importance. Of late years the annual yield has only amounted to about 14,000 oz., while the largest produce of any one year was 27,000 oz.

IRON.—Although iron ores occur in various parts of Nova Scotia, the most important deposits hitherto discovered in that province are those belonging to the "Acadia Charcoal Iron Company" at Londonderry, in the county of Colchester. The rocks, which are often well exposed in the valleys of the district, consist of grey, blue, and olive-green slaty shales, alternating with bands of quartzite and brown felspathic sandstones. The general course of the principal vein is about W. 10° N.; it has a southerly dip of about 80°, and its strike closely coincides with that of the metamorphic slaty shales and sandstones of Upper Silurian age constituting the country rock.

The vein is well seen in the bed of the Great Village River, as well as in excavations in its western bank, which rises abruptly to the height of 325 feet above its level. In the bottom of the stream the vein presents the appearance of a complicated network of fissures penetrating the quartz and slate, and apparently filled with finely crystalline ankerite. In ascending at this point the vein increases considerably in width, as well as in the proportion of iron ore which it contains. At one place where it was cut through its width was found to be not less than 120 feet. It, however, presents the aspect of a wide but very irregular vein, including large angular fragments of quartzite and of a green slate with glistening surfaces. These fragments are especially large and abundant towards the central portion of the vein, where they form a sort of irregular rocky partition. The minerals contained in the vein are chalybite, ankerite, magnetite, brown hæmatite, and red and yellow ochreous iron ores. A small quantity of heavy spar sometimes occurs in the form of minute crystals lining fissures, and as compact veins traversing the ankerite. The whole aspect of the deposit as it appears in the excavation in the river bank is extremely irregular and complicated, which arises, not merely from the broken character of its walls, but also from the number of included fragments of country rock, and from the confused intermixture of the other materials of which the deposit is composed. On the east side of Great Village River the ground does not rise so rapidly as on the western bank, and the vein is not so well exposed, although indications of it can be traced as far as the eastern branch of the stream. On the elevated ground west of the Folly River the vein is again largely developed, and an excavation near that stream shows a thickness of 190 feet of rock on the south side of it. This consists of grey quartzite, with about three feet of black slate, the beds of which are traversed by small strings of ankerite, which increase in dimensions as they approach the wall of the vein.

About seventeen feet of the vein consist principally of ankerite, while on the north ten feet of red ore are seen, without reaching the wall. The most extensive workings are upon the western section of the property, and from this part of the deposit nearly the whole of the supply of ore during recent years has been obtained. The principal excavations, however, and those from which the greater part of the ore has been raised, are confined to a length of about 700 feet, where no less than six levels have been driven into the hill at different depths. Referring to this deposit, Mr. Selwyn remarks that, although there are no good reasons for supposing that at a lower depth than has been yet reached the vein will be found of greater width than it is at present, there is, on the other hand, no reason to apprehend a falling off in this respect. Mr. Selwyn was unable to verify by personal examination many of the statements respecting the appearance and dimensions of the vein where it had been exposed in old excavations. He was, however, of opinion that the evidence he was able to collect, and the facts he was able to determine, were of such a character as fully to warrant the conclusion that no apprehension need be entertained of any failure of the supply for many years to come.[1]

The principal returns from Nova Scotia for the year 1882 were as follows:—gold, 14,107 oz.; iron ore, 42,135 tons; manganese ore, 205 tons.

[1] *Geol. Survey of Canada: Report of Progress*, 1872-3, p. 26.

British Columbia.

For our knowledge of the geology of the gold-fields of British Columbia we are mainly indebted to Dr. G. M. Dawson, of the Geological Survey of Canada, whose able papers on this subject have from time to time appeared in successive "Reports of Progress."[1]

The very general distribution of alluvial gold over this portion of British North America may perhaps indicate that its rocks of various ages are more or less auriferous. The most important gold formation, however, consists of a series of talcose and chloritic schists, blackish or greenish-grey in colour, which sometimes become micaceous, and which usually more distinctly exhibit evidences of metamorphism than do the gold-bearing schists of California. Their precise geological horizon is as yet undetermined, although it is not improbable that they may eventually be found to be the geological equivalents of some of the most productive gold-bearing rocks of California. The most extensive areas of these rocks are found in connection with the disturbed regions west of the Rocky Mountains, known in various parts of their extent as the Purcell, Selkirk, Columbia, Cariboo, and Omineca Ranges. Belts of auriferous rocks of considerable extent, and probably belonging to the same age, however, occur beyond this region, as in the vicinity of Anderson River and Boston Bar, on the Fraser; as well as at Leech River, Vancouver Island, and elsewhere.

The Cariboo district, which was discovered in 1860, has been the most productive and permanent gold-field of British Columbia. It has been described as a mountainous region, but is rather to be regarded as the remnant of a great plateau, with an average elevation of above 5,000 feet, dissected by innumerable streams which flow from it in all directions, and which join either the Fraser River or one or other of its branches. The fifty-third parallel of north latitude passes nearly through the centre of the gold-field, where streams falling rapidly over rocky beds descend into deep and precipitous valleys. With a lessening slope the rock becomes concealed by deposits of gravel, which gradually increase in thickness and extent until the valleys become flat-bottomed

[1] "Report on Leech River," *Geol. Survey of Canada: Report of Progress*, 1876-77, p. 95; "General Note on the Mines and Minerals of Economic Value of British Columbia," *ibid.* p. 103; "Report on Exploration in Southern Portion of British Columbia," *ibid.* 1877-78, p. 153 B. &c.

with occasional swampy glades, through which the stream flows tortuously with a sluggish current. Lightning and Williams' Creeks have yielded the larger portion of the gold of Cariboo. Both localities are not only rich, but are also specially adapted for deep workings from having a hard deposit of boulder clay extending beneath the beds of the present water-courses, which, to a large extent, prevents the infiltration of surface water into the workings beneath. By regular mining operations the rocky bottom of the valley is sometimes followed below 150 feet of overlying clay and gravel, the course of the ancient stream being easily traced by the polished rocks of its bed as well as by the gravel and boulders filling its channel. The richest lead is usually found in the hollow of the ancient channel, although, by following the rock-surface laterally, paying ground is often met with for some distance on either side. The old streams of Cariboo are found to have followed very nearly the same directions as their modern representatives, often crossing the valleys in various bends from side to side, but never leaving them or running across the modern drainage system as is frequently the case in the deep placers of California and Australia. On Williams' Creek, on which are situated the townships of Barkerville and Richfield, the principal workings are confined to a space of about two and a half miles in length. In this ground not only the deep channel has been worked, but also as much of the side ground as was at the time found remunerative. Many of the lateral creeks and gullies paid remarkably well, and in some places the hill sides, to a height of above 100 feet, have been sufficiently rich to make satisfactory returns by the hydraulic method of mining, which has been extensively introduced into British Columbia.

Although the production of Williams' Creek has always been much less considerable than that of Lightning Creek, Barkerville nevertheless possesses a certain local importance as the centre of a number of outlying mining districts. The mines in the gold-fields of Kootenay, Omineca, and Cassiar, situated on the same belt of auriferous rocks, resemble, in their main features, those of Cariboo. The greater portion of the Gold Range, especially towards the north, is very heavily timbered, and is often so covered with moss, peat, swamp, and tangled vegetation as to render prospecting difficult, and the discovery of rich spots a matter requiring much time and labour. Dr. Dawson, however, remarks that the recognised areas of the gold-fields will be very much extended as soon as altered conditions shall have rendered less productive deposits remunerative, when many of those which have now ceased to attract attention will again spring into importance.

In the southern portions of British Columbia gold has been very rarely found *in situ*, but it occurs in remunerative quantities in placer deposits in various localities. These generally either lie upon, or in the immediate vicinity of, certain black slaty rocks traversed by quartz veins, from the disintegration of which the alluvial gold appears to have been derived. Similar rocks, undistinguishable in lithological character from those of the typical region, may, it is true, occur on other geological horizons in the district, but no clear evidence of this has yet been obtained. The rocks are generally black or very dark, slaty, or schistose; often more or less calcareous, and not unfrequently micaceous or graphitic; more rarely chiastolitic. Dr. Dawson is of opinion that it is probably to the presence of a small quantity of organic matter in the sediments from which these rocks have been made, that their metalliferous character is due. Their fissile structure has subsequently rendered them easily permeable by waters, which have concentrated the minerals of economic value, with quartz and other crystalline materials of secondary origin, in the veins. The rocks, in their more typical localities, appear to be between those of the Cache Creek group (Carboniferous) and the Upper Mesozoic rocks similar in age to the Shasta group of California. They seem to rest conformably on the former series, and even to blend with it, while the latter is built up upon their upturned edges. They differ in appearance from the recognised Jurassic rocks of the Iltasyouco, and have yielded no fossils with the exception of some obscure impressions. While a portion of these rocks may represent Jurassic beds differing from those of the Iltasyouco region by reason of the want of volcanic materials, part at least would seem to represent the Triassic period, or even to pass downward into the Upper Palæozoic. They are not very different from the slaty rocks of the continuation of the same mountainous belt in California, which are highly auriferous, and supposed to be, at least in great part, Triassic.[1]

There are, at the present time, no important gold diggings on the lower part of the Fraser River, although it was this region that first attracted the gold miner to British Columbia; a considerable amount of gold is, however, still annually obtained, chiefly by

[1] *Geol. Survey of Canada: Report of Progress*, 1877–78, p. 153 B.

Indians and Chinamen, during the portion of the year when the water is low. From the Thompson, near Nicoamen, the first gold known to have been found in British Columbia was obtained, and this locality still continues to yield considerable quantities when the river is low. The Tranquille River, flowing into Kamloops Lake, was worked previous to 1862, and has afforded occupation to a varying number of miners ever since, although it has of late fallen almost entirely into the hands of Chinamen. The gold is, for the most part, scaly, and is often mixed with grains of platinum. At St. Louis Creek, on the lower part of the North Thompson, the gravels were formerly worked for gold. On the South Similkameen, about three and a half miles above Vermilion Forks, gold mining has been carried on for several years, although the number of men employed is not large.

Rock Creek still continues to afford profitable employment to a few men, and gold, in small quantities, has been found on several streams flowing into the Okanagan Creek; of these diggings those on Mission Creek, where the gravels of the flat rest upon Tertiary beds, have proved the most important. Cherry Creek, a tributary of the Shuswap River, has yielded a considerable quantity of gold, and still gives employment to a few white miners and a much larger number of Chinamen. Although there are numerous quartz reefs in British Columbia, some of which have, by assay, been shown to contain both gold and silver, few of them appear to have been worked.

According to Dr. Dawson, the Leech River, in Vancouver Island, was discovered to be auriferous in 1868. For some time it was generally thought that the district would prove to be a permanently productive gold-field, and houses and stores were erected accordingly. About £20,000 worth of gold is said to have been obtained in a comparatively short time from these diggings, but they are now entirely abandoned. Gold occurs in Queen Charlotte's Island, both in the alluvium and in quartz veins, but has not been extensively worked.

It is estimated that the value of the gold produced in British Columbia during the year 1881 amounted to about £240,000, and that the total value of that metal obtained since its discovery in 1858 may be taken, approximately, at £9,350,000.

Small nuggets of native silver have been occasionally found in gold placers on the Similkameen and Mission Creeks, besides which a rich silver ore, which is probably freibergite, occurs in small and irregular veins at Cherry Creek. These veins are enclosed in greyish or blackish-grey slates, and the veinstone is principally composed of quartz; assays of this ore have sometimes yielded as much as 658 oz. of silver to the ton. Nodules of argentiferous galena found in the sluice boxes on Cherry Creek, but above the known lodes, have assayed as much as 220 oz. of silver to the ton, and would indicate the existence of veins which have not yet been discovered.

On the north side of Copper Island, a band of schist about six feet in thickness exhibits a bright copper stain, and on examination is found to be impregnated with copper pyrites, to the decomposition of which, on the surface, the coloration is due. Fragments of rich copper ore, as well as rounded pieces of native copper, have been found on the Thompson. Native copper has also occasionally been found on the Fraser, and less frequently on the Similkameen.

Bismuth in the form of sulphide, enclosed in thin veins of quartz, has been found on the north-east side of Little Shuswap Lake.

Magnetite occurs in considerable quantities in Cherry Bluff, Kamloops Lake, and on Iron Mountain; it is also reported to exist in a vein several feet in width, in a ravine half a mile below Nicoamen. According to Mr. Richardson, clay-ironstones are of frequent occurrence in the coal rocks of Vancouver and Queen Charlotte's Islands. The nodules vary in weight from less than a pound to above a ton, and he is of opinion that at Baynes Sound Mine a sufficient amount could probably be obtained to supply a blast furnace.[1]

NEWFOUNDLAND.

The most important mines in Newfoundland, which is the only portion of British North America not included in the Dominion of Canada, are those of Betts' Cove and Little Bay, situated on the north-eastern part of the island, where the deposits appear to occur in rocks belonging to the Quebec group.

Dr. Sterry Hunt[2] regards the Quebec group as of great economic importance, as it is the principal metalliferous formation of large areas in North America. "To it belongs the gold found along the Appalachian chain from Canada to Georgia, together with the ores of lead, zinc, copper, silver, cobalt, nickel, and chromium. The latter metals, particularly chromium and nickel, are constantly associated

[1] *Geol. Survey of Canada; Report of Progress*, 1872-73, p. 81.
[2] *American Journal of Science*, vol. xxxi. 1861, p. 401.

with the ophiolites and other magnesian rocks of this series, while they are wanting in similar rocks of Laurentian age. The deposits of copper ore in East Tennessee, and the similar ores in Lower Canada, belong to this group. The ores of lead, copper, zinc, cobalt and nickel, of Missouri, and the copper of Lake Superior, also occur in rocks of the same age, which appear to be pre-eminently those of the metalliferous period." The ore at these mines occurs in deposits under conditions strikingly similar to those known to prevail in Eastern Canada, and to characterize rocks of apparently contemporaneous origin.

The production of copper ores at Betts' Cove and Little Bay, from the commencement of shipments in 1875 to the end of 1882, was as follows:—

	Tons.
1874 / 1875	8,000
1876	18,000
1877	44,000
1878	25,000
1879	25,460
1880	20,920
1881	24,200
1882	16,430
	182,010

The ore consists of a mixture of iron and copper pyrites containing about 7 per cent. of copper, with but little silica, and is remarkably free from arsenic. The Little Bay Mines were only opened in 1878, so that all the ore shipped previous to that year must have come from the Betts' Cove Mines only.

MEXICO.

The mountains in the extreme south-east of Mexico are mainly composed of porphyry with limestone and clay slate, in the latter of which veins of silver, copper, and lead ores, frequently occur. Granite forms the foundation of the central table-land, but its upper strata exhibit an extensive area of porphyries rich in the precious metals, together with basaltic lavas, trachytes, clay slates, amygdaloids, syenites, serpentines, dolerites, limestones, and sandstones. The Cerro del Mercado, in Durango, is said to consist chiefly of iron ore. The mineral products of Mexico are perhaps richer than those of any other country, and include gold, with ores of silver, iron, copper, lead, tin, and quicksilver. Among the most celebrated mines are those of Guanaxuato,[1] which were opened by the Spaniards at the beginning of the sixteenth century. Their production of gold and silver, from 1701 to the end of 1865, has been estimated at 521,106,638 pesos, or 2,600 millions of francs. Sedimentary rocks, of which the exact geological horizon has not been determined, contain the celebrated lode known as the Veta Madre. This deposit, which is one of the most important in the world, coincides exactly in strike (45° to 50° N.W.) and dip (45° S.W.) with the bedding of the country rock, and, consequently, may be regarded as a bedded lode. The clay slates are probably of Devonian age, while the conglomerate beds belong to the New Red Sandstone period. In the Valenciana and Rayas Mines the lode is most productive at the contact of these two rocks, and has a width of 150 yards, with from 90 to 120 yards of ore ground. The veinstone consists principally of amethystine quartz and calc spar, enclosing interstratified fragments of country rock. Among the other minerals present, gypsum, spathic iron ore, fluor spar, apophyllite, and asbestos are the most common; heavy spar is entirely absent. The curious interpolations of talcose rocks impregnated with silver ore, called *jabones*, which are found in La Luz and in some other lodes, also occur in the Veta Madre. The metals and ores are native gold, native silver, argentite, and, more rarely, stephanite, pyrargyrite, fahlerz, galena, and blende. Copper pyrites and iron pyrites are of frequent occurrence, the latter being always argentiferous. Geodes are plentiful, and in them all the above-mentioned minerals occur in a crystallized form. In the lodes of Guanaxuato the ore is first found at a depth of about forty fathoms, and at from 200 to 250 fathoms the ores become so rich in antimony and lead as to be no longer adapted for amalgamation. In addition to the Veta Madre two other systems of lodes are met with in the neighbourhood of Guanaxuato.

1st. At Santa Rosa the porphyry is traversed by lodes containing silver ores, native gold, and quartz.

2nd. The lodes of La Luz traverse diorite in a direction 15° to 45° N.W., and with a dip of from 50° to 70° S.W. The veinstone is quartz and calc spar, with masses of the talcose rock above referred to impregnated with silver ores, known as *jabones*, which form the principal source of the riches of La Luz.

[1] E. Tilmann, "Der Bergbau von Guanajuato," Münster, 1866.

The rich silver lodes in the grauwacke of Zacatecas, north-west of Guanaxuato, appear to be very similar to the Veta Madre. Fourteen leagues north-west of Zacatecas is the city of Fresnillo,[1] at the foot of a mountain known as the Cerro de Proaño, which is intersected by silver-bearing veins, of which the number is stated to exceed fifty. These are all true veins, enclosed either in grauwacke or Devonian clay slate. These lodes carry three classes of ore, respectively distinguished as *colorados*, *negros*, and *azulaques*.

Los colorados, the red ores, are distinguished as carrying chiefly native silver, silver chloride, or chlorobromide (*plata verde*), mingled with reddish iron oxides and quartz, rarely with remains of unoxidized ores. In short, the red ores mark the zone of decomposition influenced by the atmosphere and its waters; the depth to which they penetrate varying considerably in different veins. *Los negros*, the black ores, are essentially a quartzose veinstone carrying black sulphides of silver, argentite, stephanite, pyrargyrite, &c., with native silver and iron pyrites. *Los azulaques*, or bluish ores, are essentially peculiar to the veins of the Cerro de Proaño, and consist of the same ores found in the adjacent veins, but distributed in the body of the country rock for a distance of from sixteen to thirty-two inches beyond the lode. For this distance the country rock is found to be impregnated with iron pyrites, argentite, horn silver, and native silver, in thin coatings. The total value of the silver produced by the Cerro de Proaño mines, from 1853 to 1862, was $9,825,595.

The mining district of Tatatila and Zomelahuacan [2] is seven geographical miles from Jalapa. The district is formed of limestone, greenstone, porphyry, and trachyte, and the lodes occur most frequently in the limestone, rarely in the greenstone and porphyry, and never in the trachyte. The lodes, the number of which is very great, are on an average from three to six feet in width, dip at a great angle, and course nearly north and south. Four distinct groups of veins are distinguished, namely :—

1. Auriferous lodes containing native gold enclosed in quartz coloured by iron oxide.

2. Silver lodes containing argentiferous ores in a gangue of calc spar and quartz.

3. Lodes containing argentiferous galena, quartz, and calc spar.

[1] B. Silliman, "Sketch of the Great Historic Mines of the Cerro de Proaño at Fresnillo," New Haven, 1883.

[2] Richter und Hübner, *Zeitschr. Berg. Hütt. Salinenw.* vol. xxi. 1873, p. 26.

4. Copper ore veins, coursing very irregularly, containing auriferous copper pyrites and variegated copper ore.

The ore masses of La Concepcion Mine, which do not belong to any one of the above groups, as they contain at the same time auriferous quartz, lead, silver, and copper ores, are among the most important.

Near Pachuca,[1] twenty-two leagues north of the city of Mexico, is the mining village of Real del Monte. The Sierra de Pachuca at this point is composed of variously coloured porphyries invariably forming the matrix of the ores; these being never found in the younger eruptive rocks which burst through the porphyries. Stratified rocks do not occur in the neighbourhood either of Pachuca or of Real del Monte. The lodes, which are numerous, course nearly east and west, and are, generally speaking, parallel; they usually dip 70° S., but in some exceptional cases their dip is towards the north; cross lodes, coursing from north to south, are rare, and have no great thickness. The veinstone chiefly consists of quartz and decomposed porphyry, while calcite is of rare occurrence, and heavy spar is still less abundant. Native silver and stephanite are common, while pyrargyrite, blende, and copper pyrites are comparatively rare. The average percentage is from ·15 to ·18 of silver, which contains ·2 per cent. of gold. The widest lode is that of Arevalo, near El Chico, which is from sixty-four to seventy-five feet in width, but contains much worthless material. The lode of greatest extent is the Veta Biscaina, which may be traced for 5,000 fathoms along its strike, and is perhaps connected with the Veta Madre of Guanaxuato.

The Jocuistita silver mine is situated about 100 miles north of Mazatlan, Sinaloa, at an altitude of 3,500 feet above the sea level. During the year ending 1st June, 1882, 5,500 tons of ore from this mine were smelted on the spot, yielding $1,010,529 of bullion.

The output of precious metals in Mexico in 1881 is officially stated at $29,713,355.[2] In 1880 the production was, gold $989,161, silver $25,167,763.[3]

[1] Richter und Hübner, *Zeitschr. Berg. Hütt. Salinenw.* vol. xxi. 1873, p. 103.
[2] B. Silliman, "Cerro de Proaño," p. 12.
[3] C. King, "Production of the Precious Metals," Washington, 1881.

SOUTH AMERICA.

BRAZIL.

Brazil[1] has long been celebrated for its gold mines, which were first extensively worked about the beginning of the last century, and have, in the aggregate, afforded very considerable amounts of that metal. The large quantities of gold produced in Brazil during the eighteenth century were almost exclusively the yield of alluvial washings, principally in the province of Minas Geraës, which have become to a great extent exhausted, so that the gold now produced is almost entirely the result of deep mining in solid rock. Many of the auriferous deposits of Brazil differ essentially in character from those of most other countries, since the gold is often disseminated in metalliferous strata rather than enclosed in auriferous veins.

The richest portion of the province of Minas Geraës is that situated between Congonhas do Campo on the south, Candonga on the north, the tributaries of the Rio Doce on the east, and the Rio das Velhas on the west. The auriferous series is here made up of granite and gneiss, overlain by micaceous and talcose schists with interstratified seams of quartzite, which usually contains either mica or talc. These micaceous rocks are succeeded by clay slate, and often enclose lenticular masses of quartz. The clay slate is followed either by an inconsiderable stratum of granular quartz, or, more frequently, by thin bands of magnetite and specular iron ore alternating with granular quartz. The characteristic gold-bearing rocks of Brazil are known as *itacolumite*, *itabirite*, and *jacotinga*.

Itacolumite is a friable sandstone consisting mainly of quartz sand, but containing talc or mica, and sometimes also possessing a certain amount of flexibility when in thin laminæ. *Itabirite* is a mixture of specular iron ore and magnetite with a variable amount of quartz, and is either granular, schistose, or compact.

[1] W. J. Henwood, "Metalliferous Deposits," *Trans. Roy. Geol. Soc. of Cornwall*, vol. viii., Penzance, 1871; O. A. Derby, *American Journal of Science*, 1882, p. 178; J. A. Phillips, "The Mining and Metallurgy of Gold and Silver," p. 80, London, 1867.

Jacotinga consists of micaceous iron ore, brown iron ore, and quartz; the latter usually in a state of granular disintegration. Oxide of manganese, talc, iron pyrites, and massive iron glance are its chief accessory minerals. The granite of Candonga contains gold alloyed with palladium. The slaty ironstones or ferruginous sandstones often assume the form of lenticular beds, of which the central portions occasionally contain flakes and grains of gold, sometimes isolated, but at others connected with one another by threads and filaments of that metal. Towards the edges and sides of these auriferous bunches the particles of gold gradually diminish in size and become less plentiful, until the rock at length assumes, in all respects, the appearance and composition of ordinary jacotinga. At Gongo Soco a lenticular mass of itabirite is both enclosed in, and penetrated by, veins of auriferous jacotinga. The gold of this formation is always alloyed with silver and copper; and sometimes also with platinum and palladium.

At Saõ Joaõ d'El Rei there are auriferous deposits which were for many years worked with great profit, the gold having been principally obtained from a conglomerate containing rolled pebbles of itacolumite and of unctuous schists. The celebrated Morro Velho Mine is situated fifty miles south of Ouro Preto, in the province of Minas Geraës, and was for a time worked by native miners; but on the failure of the Saõ Joaõ d'El Rei mines it was purchased by the St. John del Rey Company, and has, for many years, been worked by them with success.

The gold is obtained from a quartz lode enclosed in clay slate, which, although irregular, both in direction, dip, and dimensions, is strong, and generally well defined. The vein chiefly consists of a mixture of magnetic, arsenical, and common iron pyrites, disseminated in a quartzose gangue; being composed approximately of 40 per cent. of quartz and 60 per cent. of various metallic sulphides. The arsenical pyrites carries most of the gold, the smallest grain of which is rarely seen previous to the concentration of the ore. Arsenical, magnetic, and ordinary iron pyrites respectively predominate at different points, while calc spar, brown spar, and, more rarely, yellow copper ore are also present in the vein, which is not unfrequently traversed by clay slate and barren white quartz. When pyrites is entirely absent, gold in appreciable quantity is rarely present.

The Morro Velho Lode is in some places more cavernous and less close in its texture than in others, but where drusy cavities are plentiful the yield of gold invariably diminishes. The most productive matrix for gold is a compact mixture of quartz and pyrites, enclosing varying quantities of country rock. The great metalliferous deposit known as the Cachoeira, Bahu, and Quebra Panella, is one continuous, but very irregular, vein varying in width from seven to seventy feet, and at one point reaching 100 feet in thickness. The average width of this deposit at a depth of 176 fathoms in the Cachoeira, and of 165 fathoms in the Bahu workings, was 19 feet, and stoping ground extended over a length of about 807 fathoms. There is also a north branch called the Gamba separated from the main deposit by a band of country rock, which, although containing a certain amount of gold, is too poor to admit of being worked at a profit.

The shafts, so-called, as the whole of the lode has been excavated from the surface, are carried down at an inclination of about 45°, and the mineral is brought up by strong kibble-like carriages each holding a ton.

The stamping mills, as well as all the other machinery, are driven by water-power. The average yield of the ore at Morro Velho has been about 4,333 oitavas of gold alloyed with silver, or as nearly as possible half a troy oz., value 32*s.* 6*d.*, per ton; but this yield has of late fallen off.[1]

In 1875 the mines belonging to the St. John del Rey Company produced bullion to the value of £144,072; in 1876 the value of the gold and silver obtained amounted to £247,820, and in 1877 to £176,580. From the fiftieth annual report of this company it would appear that in 1880 they stamped 63,540 tons of ore, and realised a net profit of £63,000.

The mines of Gongo Soco, about twenty miles east of Morro Velho, were at one time very productive, and other gold mines have been worked at Rossa Grande, Morro de Santa Anna, in the Serra of Cata Branca, and in some other localities. A very large portion of the province of Minas Geraës is more or less auriferous, and gold is likewise found in many parts of the provinces of Bahia, Pernambuco, Parahiba, and Rio Grande do Sul. Gold washings occur in almost all parts of the country, but they are generally carried on in a very rude and irregular manner.

Soetbeer estimates the value of the gold production of Brazil from the year 1691 to 1875 at £144,668,475.

Iron ores[2] abound in almost every part of Brazil, and the

[1] The gold obtained at Morro Velho is usually alloyed with about 20 per cent. of silver. An oitava is 2 dwt. 7·343 gr. troy.

[2] A. de Bovet, *Ann. des Mines*, vol. iii. 1883, p. 85.

deposits which occur in the province of Minas Geraës alone would appear to be almost inexhaustible. In this province a superficial deposit of a clastic iron ore, varying from one to four yards in thickness, extends for a great distance, resting on iron schist, mica schist, talc schist, clay slate, or itacolumite as a bed-rock. This cre is known under the name of *canga* and consists of angular fragments of magnetite, iron slate, iron glance, and brown iron stone, together with small quantities of quartzite, itacolumite, and other rocks. The cementing material, which imparts great tenacity to the breccia, is red iron ore, brown iron ore, and yellow and red ochres. The accessory constituents, originating from the older rocks in the same way as the iron ores themselves, are native gold, topaz, rutile, and diamond. The iron ores of Brazil would appear to be remarkably pure, as they rarely contain phosphorus or sulphur, but manganese is of common occurrence. Deposits containing gold and diamonds are almost the only ones which in Brazil have been extensively worked. Copper, manganese, and lead ores are said to be abundant.

CHILI.

Chili is rich in minerals; and among its metals are gold, silver, copper, lead, antimony, cobalt, nickel, zinc, bismuth, iron and quicksilver. Gold is found in quartz veins running nearly north and south, and is accompanied by galena, blende, copper pyrites, iron pyrites, and iron glance; but the chief proportion of the gold produced in Chili is obtained from washing the beds of rivers. Soetbeer estimates the production of gold in Chili from 1545 to 1875, a period of 330 years, at £36,772,200. The richest silver mines are found in the Upper Jurassic rocks of the province of Atacama. The most productive districts are Chañarcillo, Tres Puntas, Florida, and Caracoles.

The lodes of Chañarcillo[1] occur in beds of a bluish limestone of Jurassic age, interstratified with various metamorphosed rocks. The varying nature of the country rock through which the veins descend has a very decided effect on their contents. They run along the side of a short range of hills, and the general direction of their strike is north-east, the dip being north-west. There are, however, lodes which dip to the south-east, but although many of these have been explored to a considerable depth, they have, generally

[1] For particulars relative to the mines of Chañarcillo, Rosario, Panulcillo, and Carrizal Alto, I am indebted to Mr. M. H. Gray, A.R.S.M., who kindly placed at my disposal his notes on the metalliferous deposits of Chili, made during a recent visit to that country.

speaking, been found to give unsatisfactory results. The principal lodes at Chañarcillo are four in number, namely, the Veta Colorado, the Veta Cache, the Veta Descubridora, and the Veta Candelaria. The first two run nearly parallel at a distance from one another varying from actual contact to fourteen yards, the Veta Cache being the more irregular vein of the two. These lodes have a strike of 20° E. of N., and the Veta Descubridora has a similar direction, while the Veta Candelaria courses 45° E. of N. cutting through the other three lodes; but the points of intersection do not, as a rule, show any increase of richness. These veins, which have been traced for a distance of a mile and a half, are accompanied by others of a secondary character, and these by still smaller ones which are nevertheless of considerable importance. The lodes are much affected by the nature of the enclosing rock. They become narrower in unfavourable rocks, but, in those of a contrary nature, the lodes become not only wider and richer, but the walls also become impregnated with ore to such an extent as to allow of their being profitably worked for a distance of sometimes nine feet from the lodes. According to Mr. Gray, the Chañarcillo lodes traverse various beds of rock occurring in the following order:—

Class of Rock.	Thickness.	Contents of Lodes.
1. Stratified calcareous rocks .	660 feet.	Iodide, chloride, and native silver.
2. Intrusive rock	830 ,,	Narrow lodes, calc spar. No silver ore.
3. Carboniferous limestone . .	80 ,,	Argentite, ruby silver and native silver.
4. Metamorphosed and siliceous strata	400 ,,	Dead ground, except a layer of 35 ft. in centre of strata, making rich in silver ore in the Bocona Mine alone.
5. Calciferous-bituminous strata	330 ,,	Native silver, antimonial ores, arsenides, and sulphides.
6. Metamorphosed rocks . . .	660 ,,	Dead ground.
7. Calciferous strata	unknown.	Arsenides and sulphides of silver.

From the surface for some distance downwards the lodes are filled with a soft clayey material, containing iron ochre, calc spar, heavy spar, malachite, and native silver, together with chloride, iodide, and bromide of silver, *metales calidos.* Occasionally small fragments of undecomposed sulphuretted ores are met with in these gossans. At a depth varying from thirty-five to eighty-five fathoms, the *metales calidos* disappear, and in their place *metales frios,* consisting of silver glance, polybasite, pyrargyrite, blende, and galena, make their appearance; but iron pyrites is of somewhat rare occurrence.

At Caracoles, on the frontier of Bolivia, the Upper Jurassic limestones and marls are traversed by quartz-porphyries and compact greenstones, the lodes, from eighteen inches to fourteen feet in width, being generally productive in the porphyry. They usually contain native silver, with the chloride, bromide, and iodide of that metal, while the gangues vary in the different lodes; some consisting of calcite, gypsum, heavy spar, hornstone, and decomposed porphyry, others of quartz and heavy spar; while a few consist of heavy spar only.

At Arqueros, in the province of Coquimbo, heavy spar lodes, rich in silver, occur in Jurassic limestones traversed by porphyries. The ores consist of native amalgam, native silver, antimonial silver, silver chloride, stephanite, speiss cobalt, fahlerz, erubescite, and copper pyrites.

Although the amount of silver raised in Chili is very considerable, copper is, nevertheless, the most important product of the country. The principal copper mines are situated in the provinces of Atacama, Coquimbo, and Aconcagua, and the most important are those of San Juan and Carrizal near Copiapo, La Higuera near Coquimbo, and Tamaya, about sixty-five miles from Coquimbo, situated in an elevated mountain district.

At the Rosario copper mine, situated 2,680 feet above sea level, there are two main lodes running parallel to one another, and only a short distance apart. The more regular of the two is the Veta Negra, which lies on the foot-wall side, striking 10° W. of N. and dipping S. of W. The Veta Verde is on the hanging-wall side and, although irregular, considerably resembles the Veta Negra both in strike and dip. There is also a lesser vein joining the other two, their junction being very rich; both veins are intersected by cross-courses. The breadth of the lodes varies from one up to fourteen fathoms, the latter width being only attained where the three veins come together. The Veta Verde, undulating upon the Veta Negra, has produced many rich bunches at the points of junction. The gangue is almost entirely felspathic with a little hornblende and calc spar, while the walls are of diorite in which epidote and magnetite are accessory constituents.[1]

There are carbonates and silicates of copper near the surface, especially on the Veta Verde, but these do not extend to any considerable depth. Then follows purple ore; but the principal part of the mine is worked on yellow copper pyrites; the lowest workings being at a depth of 298 fathoms. The Panulcillo copper

[1] J. Lipken, *Berg. und Hüttenm. Zeit.* 1877, p. 129.

mine is forty-five miles from Coquimbo, the ore being obtained from a contact deposit and not from a true vein. The ore-bearing ground is divided into two parts by a cross-course and the two divisions are worked separately, being respectively known as the North and South Mines. These ore masses strike 5° W. of N. In the North Mine the deposit goes down perpendicularly, but in the South Mine it dips 63° E.; the cross-course striking 45° E. of N. The North Mine deposit has a length of 900 feet along the strike, and the widest part yet opened measures seventy feet, the narrowest stope being about forty feet across. The east side is composed of stuff too poor to work. The western wall is of porphyry and has a good selvage, while the eastern is composed of mica schist and is rather indefinite. The ore is copper pyrites, with a gangue of crystalline tourmaline. The deposit at the South Mine is 600 feet long, and fifty feet across in its widest part. The eastern wall of this lode is of mica schist, and the western wall of crystalline limestone containing crystals of mica. The ore and gangue are of the same character as those in the North Mine.

Carrizal Alto was once a very important copper-mining district, but is now decidedly on the decline, the copper at present produced coming from ground already worked over. The lodes of this district, which run more or less parallel to one another with a north-north-east direction, are frequently crossed by igneous dykes, and are usually enriched where so intersected. As a general rule, from the outcrop to a depth of twenty-five fathoms the ores are carbonates; for the next ten fathoms friable melaconite is met with; while below this comes yellow copper pyrites with iron pyrites to a depth of 240 fathoms. After this, so far as has hitherto been explored, dead ground prevails. Many other important copper mines are worked at various places in the Northern Provinces.

The copper exported from Chili during the year 1881 amounted to 38,030 tons and in 1882 to 42,960 tons. These figures represent fine copper, and therefore include the metal contained in both ore and regulus. Of the total amount of copper exported from Chili during 1882, 84 per cent. was in the metallic state, 14 per cent. as regulus, and about 2 per cent. in the form of ore.

In Chili the most common ore of cobalt is arsenical cobalt, and the most important lode is the Veta Blanca of San Juan; glance cobalt and erythrite are also worked at Tambillos and at Huasco.

BOLIVIA.

The great extent and variety of the mineral productions of Bolivia have given it an importance which it could not otherwise have possessed. Gold is found in considerable quantities in the mountainous parts of the country, and occurs in lodes in association with silver and other ores. The greater portion of this metal is, however, obtained from washings in the beds of rivers. Several districts in Potosi, Chuquisaca, Santa Cruz and Tarija, are auriferous. The production of gold in Bolivia in the year 1881 was, according to Burchard, about 3,500 oz.

Silver is however the staple metallic production of Bolivia, the mines of Potosi[1] being well known for their almost fabulous riches. They were discovered in 1545, and their annual production was estimated by Chevalier in 1845 at from 48,000 to 60,000 lbs. troy. The celebrated mountain of Potosi rises 2,697 feet above the great square of the city of that name, which is situated at its base. It has a somewhat conical form, and consists, from the summit to a depth of about 200 fathoms, of quartz-porphyry. From this point clay slate forms a mantle round the porphyry. The labour of the miners has been confined to the upper portion, where about sixty lodes, coursing N.E. and dipping from 65 to 70° S.E., together with various workable strings of ore, traverse the porphyry. The lodes continue down into the deeper parts of the mountain, sometimes passing out of the porphyry into clay slate, in which, however, they become less productive. The minerals contained in the lodes are quartz, iron pyrites, pyrargyrite, fahlerz, cassiterite, and silver chloride, together with native silver.

The silver mines in the province of Chicas, have acquired considerable celebrity on account of the richness and quantity of their ores. The once famous mines in La Paz are now abandoned, while those of Arque, Lipez, and of the department of Oruro, are not regularly worked. In the last-named district a porphyry has burst through the clay slate, and is traversed by numerous lodes coursing N.E. and dipping from 45° to 85° N.W., with a thickness varying from three inches to several yards. The vein-stuff consists principally of porphyry impregnated with iron pyrites. Pyrargyrite, stephanite, plumosite, antimonial glance,

[1] H. Reck, *Berg. und Hüttenm. Zeit.* 1858, p. 275; *Ibid.* 1866, p. 389.

argentiferous fahlerz, and cassiterite occur in strings. Near the surface *pacos* ores are found, while lower down *mulatos* and *negrillos* make their appearance.[1] In 1870 silver deposits were discovered at Caracoles, in the desert of Atacama. Burchard states that in 1881 the silver production of Bolivia amounted in value to $11,000,000.

Copper takes the next rank among the valuable metals of Bolivia, and occurs in the departments of La Paz, Potosi, Chuquisaca, Oruro, and Beni. At Algodon Bay, in the vicinity of the desert of Atacama, lodes from three to six feet in thickness occur in diorite and syenite, and contain copper glance, together with copper pyrites. They also contain atacamite, but azurite and malachite are never met with; the Atacamita Lode is especially rich in atacamite, which occurs mixed with red copper ore.

The value of the copper exports from Bolivia to the United Kingdom during the year 1882 was as follows:—

Ore	£46,794
Regulus	80,391
	127,185

Tin is mined to a small extent in Potosi and Oruro, where it is found in association with silver ores. Cinnabar and lead ores are also met with.

PERU.

Peru has long been famous for its wealth of silver and gold. Soetbeer estimates the amount of gold produced during the years 1851 to 1875 at 20,570 lbs., worth £1,304,325. The total export of gold from Peruvian ports during the year 1877 amounted to 35,633 oz.

Silver is, however, more widely distributed over the country than is gold. The silver mines of Huantajaya, Pasco, and Chota, are remarkably rich, and great improvements in the system of mining were introduced into this district by the celebrated Richard Trevithick.

The mines of Cerro de Pasco are perhaps the most remarkable, and may be taken as a type of the others. Among the principal ores are the so-called *pacos*, the *colorados* of the Mexican miners, which are ferruginous earths mixed with silver ores resulting from the

[1] H. Reck, *Berg. und Hüttenm. Zeit.* 1868, p. 77.

decomposition of argentiferous sulphides. De Rivero[1] considers the Santa Rosa deposit not to be a true vein, since it is parallel with the formation. The hanging and foot walls are of a different character, and the gangue has no crystalline comby structure. The mines of Pasco were discovered by accident in 1630, and are still the most important in the country. Their production was, in 1870 to 1875, 1,241,888 marks; in 1876, 169,849 marks, and in 1877, 178,469 marks, the mark being 230·046 grammes. The annual production of silver in Peru is estimated at about 345,000 marks.[2] The silver ores of the north, and more particularly those of Scalpi, generally contain gold. These ores are for the most part sent for treatment to Swansea, and a small portion to Freiberg and Clausthal.

Ores of mercury are widely distributed, and are said to have been known to the inhabitants before the invasion of the country by Europeans. The deposits of Huancavelica are the most important, and have been worked since 1566; the cinnabar is found in Carboniferous sandstones and clay slates, and is very similar in its mode of occurrence to that of Almaden. Crosnier,[3] who went out for the Peruvian Government in 1851, reports that these quicksilver deposits have nothing in common with true veins, but everything appears to indicate that the ore was introduced in a state of vapour at the time the strata were elevated to their present almost vertical position.

Copper is of frequent occurrence in Peru, but lead and iron ores, although plentiful, are not worked.

GUIANA, &c.

The vast territory of Guiana is divided into Brazilian Guiana, Venezuelan Guiana, and Colonial Guiana. The first two divisions, comprising five-sixths of the entire region, are now included in Brazil and Venezuela respectively, while the last division is composed of the territories of British, Dutch, and French Guiana. Over the whole of this large country gold is found both in placers and *in situ*, and there can be no doubt that a great South American gold-field is rapidly becoming developed which promises to rival the three great gold-fields of North America, Australia, and Siberia.

[1] *Ann. des Mines*, vol. ii. 1832, p. 169.

[2] "Report of the Director of the Mint upon the Production of Precious Metals in the U.S." 1882, p. 535.

[3] *Ann. des Mines*, vol. ii. 1852, p. 1.

VENEZUELAN GUIANA.[1]—The most important mine of Venezuelan Guiana is El Callao, which may claim to be ranked among the richest gold mines of the world. The workings are about sixty fathoms in depth, the lode varying from four to seven feet in width, with an underlie of 52°. Generally the quartz is white, but occasionally it is tinged greenish by a chloritic mineral; it contains much free gold with but a small amount of sulphides. According to Dr. Foster, the Callao Lode courses north and south and dips west, the country rock being felstone with a little iron pyrites. The miners consider the presence of iron pyrites a favourable sign with regard to the productiveness of the lode. The lode had, in 1869, been worked for a distance of 100 fathoms along the strike, and is said to die out southwards. From 1871 to 1879, a total quantity of 67,362 tons of quartz was crushed, from which 252,973 oz. of gold were extracted. In 1880 the Callao Company's mines crushed 18,624 tons of quartz, giving 54,013 oz. of melted gold, worth £205,969.

The Chile Lode is probably, after Callao, the most important in the Caratal district. The main lode courses E. 10° N., dips 45° to 60° S., and varies from two to six feet in width. It consists mainly of quartz with brown oxide of iron, chlorite, talc, a white earthy mineral like kaolin, and visible gold. The country rock is composed of talcose clay slate, and a ferruginous hornstone also frequently occurs. The latter rock, called "porphyry" by the miners, is regarded as a favourable indication for gold. The Chile Company's mines in 1880 crushed 6,762 tons of quartz, giving 14,525 oz. of melted gold with a fineness of 912. The Potosi mines produced, in 1880, 23,280 oz. of gold, worth £90,210.

Gold mining, which is the chief and almost the only industry of the Caratal district, dates from 1866, since which time to December 1879, a total of 770,026 oz. had been shipped at the port of Ciudad Bolivar; the amount shipped in 1879 being 107,722 oz.

DUTCH GUIANA.—Gold digging commenced here in 1875, and the development of this branch of industry has since marvellously increased. The production in 1879 was 679,914 florins.

FRENCH GUIANA.—Indian tradition' long ago affirmed the presence of gold in French Guiana, and both Humboldt and Buffon were of opinion that the geological character of the country rendered its presence probable. The diggings of Pastroptôt, in the district

[1] C. Le Neve Foster, "On the Caratal Gold Field," *Quart. Journ. Geol. Soc.* vol. xxv. 1869, p. 236; "Concession relating to the State of Guiana, South America, and Reports on its Produce, Gold Fields, &c.," London, 1882.

of Mana, produced 300 lbs. of gold during the first six months of 1879. The auriferous bed is composed of quartz fragments resting on clay, with a covering of fine sand.

BRITISH GUIANA.—The rivers of British Guiana are known to be auriferous, but, beyond washings by the natives, no mines or placers are worked for that metal.

UNITED STATES OF COLOMBIA.—The United States of Colombia have been long known as a gold-producing country, gold mining having been commenced by the Spaniards in 1537. The annual production is now about $4,000,000. The gold of Giron is perhaps the purest unrefined gold in the world, as its fineness often reaches twenty-three and a half carats. The production of silver in 1880 amounted to $1,000,000.

The production of this great gold-field in South America, north of the River Amazon, was recently as follows: [1]—

U. S. of Colombia,	1880	$4,000,000
Venezuelan Guiana	,,	2,200,000
Dutch Guiana	1879	272,000
French Guiana	,,	200,000
	Total	6,672,000

ARGENTINE REPUBLIC.—It is stated by Mr. Rickard, that at the period of his writing (1863) there were twenty-eight gold mines, the same number of placer washings, forty-six silver mines, and eleven copper mines working in the Republic, producing 3,654 oz. of gold, 418,201 oz. of silver, and 15,032 cwts. of copper.[2] Clarence King estimates the production of the precious metals in the Argentine Republic during the year 1880 as:—gold $78,546, silver $420,225.[3]

Among the most important mines are those in the province of Rioja, where the formation is Silurian. The copper ores of this region always contain both gold and silver, while auriferous veins of quartz are of not unfrequent occurrence.

[1] "Report of the Director of the Mint upon the Production of Precious Metals in the U.S.," p. 543, 1882.
[2] F. Rickard, "Mineral Resources of the Argentine Republic," London, 1870.
[3] C. King, "Production of the Precious Metals," 1881.

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