R. Ellsworth Call
1891 to J. C. B.

GEOLOGY

—OF—

Colorado Ore Deposits.

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PREFACE.

This treatise contains the substance of a series of elementary lectures delivered by the author to the students of the Colorado State School of Mines. It is published with a view of meeting some of the needs of the general public, of the ordinary miner, and of the unscientific many, rather than with any idea of offering original matter for the discussion of the scientific few. The materials are derived partly from the writer's own researches, and largely from the most reliable resources available to him, such as the standard text-books and the valuable published reports of the United States Geological Survey. The writer having for a time been connected with that survey, knows full well how high a value is to be attached to those reports, which must remain for all time as a standard of reference for those interested in the geological relations of the mines of Colorado.

The first part of the work contains a rough sketch of general Geology, for the benefit of those who are not familiar with the terms used in this science. The sketch is further applied to the local geology of Colorado. The second part refers to the phenomena of veins and ores, and their surroundings, as illustrated by Colorado.

The last part contains a brief account of some of the principal mining districts of Colorado, not as official reports of those districts, but as examples to illustrate the principles of the preceding parts.

Part I.

GENERAL GEOLOGY.

To assist such of our readers as may not be very familiar with the science of Geology, in understanding such technical and geological terms as are unavoidable in this treatise, we offer a rough general outline of the earth's history, applying it afterwards to a sketch of the geology of this particular region of Colorado.

ORIGIN OF THE EARTH.

The world was not "spoken into existence ready made" in the state we now find it. It has attained this condition through a multitude of gradual changes and revolutions which have taken millions of years to accomplish. The remote history of the earth is a matter of hypothesis. There are reasons for supposing that at one time its elements were in a gaseous condition, and that this planet was an incandescent luminous cloud revolving through space, gradually consolidating into a molten ball, surrounded still by an atmosphere of gases, a condition perhaps not unlike the present one of the sun, whose interior is supposed to be passing into the molten state while its exterior consists of various incandescent gases arranged more or less according to their specific gravities. The spectroscope has detected the elements of some of our earth metals and minerals in the sun in a state of vapor.

Upon the cooling of the ball, a crust formed like that on molten iron, crumpled, by contraction due to cooling, into an uneven surface with slight elevations and depressions, and doubtless broken through, here and there, by great fissures and volcanic craters, through which the molten flood beneath poured out in volumes.

Upon such a surface the gaseous atmosphere gradually condensing, descended as hot chemical rain, and filled the troughs of the crumpled surface with a hot chemical steamy ocean.

Whatever land of primitive lava arose above this ocean was battered by the waves, reduced to sediment, and deposited as the first stratum in the bed of that primæval ocean, the eruptions from below the thin crust also contributing largely to the same material.

ARCHÆAN AGE.

Thus we may suppose was formed the first stratified rock of the world which we have an opportunity of actually seeing, that is *granite* with its varieties of gneiss, schist, syenite, etc., and as this is the "beginning" age, within human observation, we call it *Archæan*, the Greek for beginning. It is, however, evident that these granite rocks which form the axes of our mountains are not the very first, because their stratification and composition show them to have been derived from the breaking up of still earlier rocks, which latter may have been the original cooling crust.

SILURIAN AGE.

Cooling and contraction still progressing on the globe, fresh and greater wrinkles were caused on the surface of its crust, and some of this granite sea-bottom was crumpled up till the crumples arose above the surface of the ocean as low islands or reefs.

The ocean had now cooled sufficiently to support marine life and so along these granite islands, corals formed reefs, shell-fish swarmed, and sea-weeds grew. Sandstones formed by the waves from the material of the granite were laid down as shore line strata, often mixed with shells, and in deeper water, coral limestone was in progress, as it is at the present day.

Hence in Colorado we find the upheaved crumpled granite of the old island, with its sandstone or quartzite beach, with fossil shells, and upon that, limestone, with fossil corals still visible. We call this the Silurian age, and the fossil shells and corals Silurian fossils, because they are peculiar to that age and quite unlike the shells and corals of the present time.

North America, at the beginning of this period, was barely outlined by a few granite islands. One formed the site of part of modern Canada, one or two reefs or islands marked the site of the eastern ranges of mountains, and a few parallel granite islands rudely outlined the site of the principal uplifts or future great ranges of the western Cordilleras. All else was Silurian ocean and that ocean was depositing its Silurian coral limestones and sandstones against these few granite islands, destined in time to grow into mountain ranges and to become the backbones of the continent.

DEVONIAN AGE.

Upon the Silurian followed the Devonian, an age characterized by extraordinary fishes. But as it is not generally represented, for some reason, in these mountains, we pass on to the Carboniferous. These ages we are speaking of are separated from one another by decided and characteristic changes in the fossil animal and vegetable life existing between one age and the other, and in various parts of the world these changes of life are marked also by great geological revolutions such as the elevation of mountain ranges, or great continental masses.

In America these oscillations between sea and land seem to have been less than in Europe, and we find a general uniform rise of the continent from the ocean and an orderly succession of strata lying against the flanks of the ever rising granite nucleus of both mountains and continent.

CARBONIFEROUS AGE.

In the Eastern States, as the continent gradually began to rise from the waters, and to the granite islands had been added a Silurian shore, and to that a Devonian shore, a kind of trough seems to have been formed between the middle and eastern part of America, which was occupied by very low, marshy land or marshy islands barely above the sea level. Upon these low-lying lands grew a dense vegetation unlike any of the present day, but resembling somewhat our tree ferns of the Southern States. This low land was subject to freshets from surrounding higher regions which periodically deluged the swamps and its vegetation with river and flood deposits of pebbles and sand, under pressure of which the vegetation was gradually turned into coal. Successive coal beds were formed by successive growths of vegetation between the intervals of periodic inundations, subsidence and upheaval, for these low lands also appear to have occasionally subsided under and been lifted up again above the sea. Finally by a grand revolution which closed the Carboniferous age in America, the coal swamps and strata were crumpled up into the great Appalachian range of mountains. In the Rocky Mountain area the marine condition seems during this time to have been the prevalent one, for we find a predominance of marine limestones and sandstones with very slight indications of coal or land plants.

In Colorado the Carboniferous limestones with fossil corals and shells in them, lie directly upon the Silurian deposits. Upon the limestones come thick beds of sandstone and shale, which latter may mark a land and fresh water state of things, resembling that in the East, for we not only find traces of coal in the South Park range and at Aspen, but also a few fossils of those strange Carboniferous tree ferns and horsetail rushes or equiseta. It was not, however, the great coal-bearing age in Colorado as it was in the Eastern States and throughout the world generally. Our great Colorado coal-bearing era is a much more recent one, viz.: the Cretaceous.

The Carboniferous, however, contains in its limestones much of our mineral wealth, such as the silver-bearing lead deposits of Leadville, Aspen and other regions.

The Silurian, Devonian and Carboniferous ages have been grouped together into one great division called the Paleozoic time or "old life" of the earth. By Paleozoic rocks then, we mean the rocks of one of these ages, or rather (in Colorado), only the Silurian and Carboniferous, as the Devonian is missing.

TRIASSIC AND JURASSIC PERIODS.

After the Carboniferous followed the Triassic and Jurassic periods, whose rocks in Colorado are marked by their prevailing red color and consist of heavy bedded red conglomerate sandstones such as may be seen in the gateway of the "Garden of the Gods" at Manitou. In South Boulder cañon, in Platte cañon, at Morrison, in Bear Creek cañon, and almost in every cañon in the foothills, in the Gunnison region and in the neighborhood of Aspen, the same red rocks are very prominent.

In South Park also they are observed on the flanks of Silverheels mountain, and in the neighborhood of Fairplay and the salt works. Besides the sandstones there are thin beds of limestone and variegated clays. The conglomerate sandstones and limestone show no evidence of fossil life, but the variegated clays in the upper portion of the Jurassic have yielded at Morrison and near Cañon City some remarkable remains of gigantic lizards called Dinosaurs. It is probable from the presence of salt and gypsum and the redness of the rocks that these red beds were laid down in land-locked salt seas or salt lakes, shunned by animal life.

The upper portions, however, show evidence of low, marshy land and fresh water, by the presence in them of turtles, crocodiles, fresh water shells and Dinosaurs or land lizards. These upper deposits may be of estuarine origin.

CRETACEOUS PERIOD.

After this followed the Cretaceous period, a very thick formation numbering several thousands of feet in Colorado, consisting in its lower and middle portion of sandstones, white limestones and very thick beds of drab clays. These are mostly marine, as shown by the sea shells found in them. The exception is the Dakota group or Cretaceous No. 1, at the base of the Cretaceous, which, along the foothills forms a prominent "hogback" of white sandstone. In this are fossil impressions of leaves of trees not unlike (but not identical with) those of the present time. The middle or Colorado group of the Cretaceous, consists of limestones and very thick beds of clay. Both limestones and clay contain quantities of fossil marine shells such as the Nautilus, Ammonite and Inoceramus, the two former resembling a ram's horn or a snake coiled up, the latter not unlike a clam shell.

LARAMIE COAL GROUP.

The upper portion of the Cretaceous is called the Laramie group, and contains our vast and valuable coal fields. Associated with these rocks we find also fossil leaves of semi-tropical vegetation, such as the palm, fig, magnolia, maple, etc. This Laramie group marks an important era in our Rocky Mountains, for it shows the beginning of the great Rocky Mountain revolution by which the granite islands against which all these marine sediments had been forming, were elevated 10,000 feet or more into mountainous masses, dragging up with them portions of the sea bottom and exposing it as land surface, draining off the shallow Cretaceous sea which had hitherto divided the eastern half of the American continent from the western, and bringing on a land and continental condition, which was completed in the following Tertiary age and has continued to the present. The Triassic, Jurassic and Cretaceous are grouped into the Mesozoic, or "middle life" age.

TERTIARY AGE.

The Tertiary age which followed is not so well represented in Colorado as the Cretaceous. It seems to mark an era of comparative rest in mountain elevation, for its sandstones and shales lie nearly horizontally on top of the upturned Cretaceous and other beds. These beds appear to have been formed by wide lakes of fresh water surrounded by tropical foliage. They may be seen capping the Divide between Denver and Colorado Springs, forming the singular "mesa" or table land country, from Castle Rock and Sedalia down to Monument Park and Austin's bluffs, east of Colorado Springs. From the singular forms cut out of these sandstones by water in Monument Park we call them the "Monument Creek Group." A similar formation is found between Colorado Springs and South Park at Florissant, right in the heart of the front range. It is a small Tertiary lake deposit remarkable for its fossil insects, petrified trees and leaves.

In the neighboring territory of Wyoming the Tertiary lake beds form the great Green River region with its fossil mammals, fishes, leaves and insects.

The Tertiary was the world's tropical summer, a period of beautiful lakes and tropical vegetation, but in certain regions it was disturbed by gigantic revolutions which upheaved the Himalayas, the Alps, and other great mountain ranges. Such revolutions as occurred in our cordillera system were marked by frightful ebullitions of lava issuing from cracks and fissures, deluging Idaho, Nevada and part of Oregon and Washington Territory. Remnants of the Basaltic flood are found in Colorado, capping our coal table lands along the foothills, particularly toward the southern portion of the State and down into New Mexico.

GLACIAL EPOCH.

The Tertiary Summer was closed by the world's great Winter, from causes which we will not here discuss. The ice from the North Pole extended its domain nearly to the Equator. All the northern temperate regions of the world were ice-sheeted, and the sheet extended itself as by long fingers down the now highly developed mountains, filling every ravine with a glacier. It was the Glacial Epoch. In Colorado these glaciers occupied every incipient cañon previously begun by streams or by folds in the strata. By their downward destructive movement they widened and deepened the cañons, gouged out the mountains, and exposed the fissure veins, and did the first great mining on a gigantic scale in Colorado. The debris they carried on their backs, dumping it at the outlet of the cañons, and when the temperature rose and the glaciers melted, all the long lines of traveling boulders scattered upon their backs were left as banks, or "moraines," or "placer" grounds along the sides of our streams and cañons, often a thousand feet above the present river bed, marking the height and thickness the glaciers once attained.

QUATERNARY AGE.

So were our cañons largely formed and so did our gold placers originate. After the Glacial Epoch a warmer period set in, which we call the Quarternary. The ice melted, vast bodies of fresh water were distributed in wide streams and great lakes over this hemisphere. The rough morainal dumps of the glaciers were sorted or "modified" by water, rolled into pebbles and sand, re-distributed along the banks of streams, and carried out into the beds of the lakes. In these pebbles and sand was much of the precious metal, robbed from the veins. The gold by its insolubility in water remains to this day in our placer beds and "wash," and is collected by sluice or hydraulic mining.

Still the agencies of nature are going on as of yore. Continents are gradually rising or sinking. Mountains are being imperceptibly elevated, water is still sculpturing them with cañons, rivers are carrying down fragments robbed from the land and depositing them in the ocean to form strata for future continents. The fires of the earth are not yet dead, for volcanoes still vomit lava. The earth is still continuing to lose heat, its crust is still contracting and wrinkling itself upward, for we find modern sea beaches raised high on our cliffs. Shocks of earthquakes from time to time prove that motion of some kind is going on beneath us, and doubtless our mountains are still rising imperceptibly, as they appear to have done in the countless ages of the past, and slowly elevating and tilting strata that since the Tertiary period have lain apparently undisturbed. I say apparently, for even the Tertiary beds show everywhere a dip of 2 to 5, and even 10 degrees, proving that the mountains have risen that much since these beds were deposited, and that they are probably still rising.

For local illustration of the foregoing, we may descend by the course of any of our streams down its canon in the mountains till it debouches on the prairie. For forty or fifty miles the profound cañon is through solid granite or gneiss. The composition of the granite is crystalline. It shows indistinct signs of once having been stratified. Its strata, moreover, shows evidence of intense folding and crumpling, as if by lateral, tangential pressure such as would be caused by contraction.

This is the Archæan granite that first lay as horizontal sandy strata in the bottom of that earliest hot and chemical ocean where it was crystallized.

It was then crumpled up into the Colorado-Front-Range island above the Silurian sea, and formed the shore line for ages of seas depositing horizontally the different strata of the Paleozoic and Mesozoic eras.

At the close of the Cretaceous or Mesozoic era it was further crumpled up from an island reef to a mountain range 10,000 to 14,000 feet above the sea level. This movement added new crumples and foldings to its already puckered strata. The heat of friction partially melted some of its material, which filled fissures caused by the uplift; hence we find dykes of feldspar or "eruptive granite," here and there. Heat also seems to have rendered the whole mass of strata more or less plastic.

As we emerge from the granite on to the foothils and prairie we encounter, as we go down the creek, the upturned beds of the various periods we have described, resting at a steep angle against the flank of the granite, in their geological sequence and order.

First are beds of sandstone and limestone, with fossils such as trilobites, crustacea, and spirifer shells, representing the Silurian. Next, variegated beds, with limestone at the base and coarser sandstone and shale near the top. In the latter some traces of coal and coal plants mark its Carboniferous character.

Upon this follows a great thickness of coarse conglomerate sandstones, variegated clays, and some limestone, all of a general red or variegated character.

These represent the Triassic and Jurassic periods, and in the clays of the latter, Dinosaur bones are found at Morrison and Cañon.

A prominent "hogback" or ridge next appears on top of the Jurassic clays. It is formed of hard white or gray sandstone, on which are some leaf impressions. It is the first group or base of the great Cretaceous period, and is called the Dakota group, or Cretaceous No. 1.

After we pass this "hogback" we generally find a flat, grassy valley, underlaid by soft, dark shales and clays, full of marine Cretaceous shells, with one or two belts of limestone, also full of large shells. Evidently this is the bottom of the Cretaceous sea, and represents the Colorado group of the Cretaceous.

The next uplifted sandstone we meet with shows sea-weed fossils in it, and a little higher up, land plants, and then two or three coal beds. This is the uppermost group of the Cretaceous, known as the Laramie coal series.

A few scattered table mountains of horizontal strata, with fossil leaves, may locally be met with, as on the Divide, which represent our Tertiary period. And lastly, on top of all these strata, both horizontal and upturned, we find scattered over "hogback" and prairie alike, the drift or "wash" of pebbles of all kinds, distributed by the glaciers and floods of the Quaternary.

Thus since we left the granite at the outlet of the cañon we have passed through and examined not less than 10,000 feet in thickness of the crust of the earth, comprising all the periods from Archæan to Tertiary and Recent We have found the strata of the several periods and epochs lying upturned against one another, like leaning rows of books, till we come to the top of the uppermost Cretaceous or Laramie coal, and then the Tertiary lies flat. We conclude, then, that the strata of all these periods and epochs were accumulated and lay undisturbed and horizontal until the close of the Cretaceous, when the granite island was elevated into a mountain. Since then elevation has been quiet or very slow.

Such are the general geological features of the eastern slope of these mountains and their attendant foothills. If we penetrate into the heart of the mountains, to the region of South Park, and thence across to the western slope, we shall find much the same features repeated, and with much the same geological history.

In South Park, on the western side of the "Front Range," we find its basin underlaid by the same rocks of the same geological periods, from Silurian to Tertiary and Quaternary, as we find on the Eastern foothills; the same Post-Cretaceous uplifting of Paleozoic and Mesozoic rocks upon the flanks, even to the top of the granite mountains, and the same pause in elevation marked by the horizontal Tertiary and Quaternary beds Also the same evidences, only much more distinct, of the former presence of glaciers, by morainal placer beds, and by the U shape of the canons, with marks of the action of Quaternary floods, following the melting of the glaciers, in the distribution of pebbles and sand all over the surface of the park. In the heart of our mountains, however, we find that the folding of the rocks was more violent. Eruptions of lava incident on such movements were more abundant, and evidences of former heat are more apparent than nearer the foothills. This is shown in the fact that the unaltered Silurian and Carboniferous sandstones we met on the foothills, are here changed by heat into hard white vitreous quartzites. The limestones in many places pass into marble, shales and clays into slates, and in the Gunnison region the Laramie coal is turned into Anthracite.

The Colorado "Front Range" and the Sawatch Range each being surrounded by the same set of marine and other strata, shows them to have had the same history; first as horizontal granite strata, next lifted into granite islands in the Silurian ocean, and lastly, at the close of the Cretaceous, elevated into mountain chains, carrying up with them the various beds so long accumulating in the seas by which they were surrounded.

With these preliminary explanations, the following epitome of a sketch of the general geological history of these mountains, from the accurate observations of the U. S. Geological survey, will be intelligible.

At the close of the Archæan era, when the earth was covered by a Silurian ocean, a large area covering most of what is now the Colorado, or "Front Range," formed a large rocky granite island, with a number of smaller islands lying to the West of it, the most important of which now forms the Sawatch Range from which it was more or less completely separated by the sea waters occupying the present depressions of the North, South and Middle Parks. During the whole of the Silurian, Carboniferous, Triassic, Jurassic, and Cretaceous periods, *i. e.*, the Paleozoic and Mesozoic times, a continuous deposit of sediment went on in the seas surrounding these islands, of materials such as sand and pebbles washed from these granite islands, and also of organic limestone derived from corals and shells.

No great disturbances took place throughout this long period, hence all the different strata with their various fossils lay for the most part conformably and horizontally one on top of the other in successive order.

Toward the close of the Cretaceous period, that is at the end of the Mesozoic, at the time of the formation of the coal beds, the seas became shallower, owing to a general elevation of land, and considerable portions of the outlying area were partially enclosed. During this time and possibly earlier, immense masses of eruptive igneous rock were forced up through the already deposited sediments still lying horizontally beneath the waters.

Unlike the lava flows of modern days, these molten masses did not spread out on the surface of the rocks, but congealed before they reached that surface either in large masses, in dykes or in sheets spread out between the strata. These phenomena are well exhibited in the Leadville, Gunnison and Aspen districts.

We do not know how long before the Cretaceous the eruptions of these igneous rocks commenced, but they certainly continued to the close of that period, for we find them traversing rocks of that age—as at Crested Butte, Irwin, and Gothic, in the Gunnison region.

Some time after the close of the Cretaceous a general upward movement took place in the Rocky Mountains, by which the existing mountain ranges or islands were crushed together, broken and elevated, and considerable areas of the adjoining sea bed were lifted above its surface.

In the general continental elevation which followed during the Tertiary period, fresh water lakes or enclosed seas were formed, in which, by the washing away of the newly made land areas, considerable sediments were deposited, such as the strata on the divide and at Florissant, and the table land country generally.

During this Tertiary era and after it, eruptions of lava also occurred, generally following the lines of earlier and older eruptions, but unlike the latter, spreading out on the actual surface of the land, and in some cases beneath the sea, as for example, the basaltic cap of "Table Mountain," (Golden), Fisher's Peak, near Trinidad, and the rhyolite capping of the mesas of the Divide.

While the general form of the mountain area was sketched out and determined in the earliest geological times it is only since the Tertiary, and in a great measure by erosion after the Glacial epoch, that the present sculpturing of the mountain forms with their ravines and canons has taken place.

GEOLOGICAL AGE OF MINERAL DEPOSITS.

At what period the different mineral deposits of Colorado were formed cannot be definitely stated.

The gold deposits of Gilpin County may have been during or after the Archæan age, since they occur in Archæan rocks, but as in the immediate vicinity of these deposits there are no later rocks to limit their exact age, they may have been before the Silurian or very much later.

The silver-lead deposits of Leadville were certainly formed after the Carboniferous, and before the mountain upheaval at the close of the Cretaceous, because in the first place, they penetrate Carboniferous rocks, and in the second place, the fissures, faults, etc., formed at the time of the Cretaceous uplift, cut through and fault these deposits.

Those of the Gunnison region are later than the Cretaceous, because they occur in fissure veins, cutting through the Cretaceous rocks, even through the Laramie coal beds.

Those of Custer and San Juan were probably formed in the Tertiary, because they traverse basalts and other lavas of "presumably Tertiary age."

CONNECTION BETWEEN MINERAL BELTS AND MOUNTAIN UPLIFTS.

In the greater Cordillera system, of which our Rockies are a part, there appears to be a definite connection between mineral belts and well-known lines and times of uplift. There are several well defined, more or less parellel mineral belts in the Cordillera system.

There is one at the foot of the Wahsatch Mountains, represented by the Utah mines, which lie in the foothills of this range with a definite relation to the main line of crests.

The gold and copper belts of California stand in a similar relation to the Sierra Nevada.

The quicksilver and cinnabar belt of California is a belt parallel to the Coast Range.

The Arizona belt lies in a northwest and southeast direction diagonally across the country.

The mining districts of Nevada cannot be so easily grouped.

Now these four distinct belts are connected with four great mountain building changes and uplifts, which the region West of the Rockies has undergone.

The last of these was after the Miocene Tertiary, resulting in the uplift of the Coast Range, together with part of Oregon and Washington Territory. The disturbing force was most powerful North and South of San Francisco, and there lies the cinnabar belt. An upheaval soon after the Cretaceous, raised the whole western central portion of the continent, now occupied by the complicated system of the Rocky Mountains.

The Wahsatch Range is the western edge of this uplift, and the dislocation took place on an old fault, coincident with the present western foot of that range, and here, as we have said, lie the mines of Utah.

The Sierra Nevada and ranges of the great basin were raised by an uplift at the close of the Jurassic.

The line of most intense disturbance coincided with the Sierra and the greatest dislocation occurred along its western foot in what is marked by the gold belt.

The earliest disturbance in the far West was that which raised the Paleozoic strata of Eastern Nevada, Western Utah and part of Arizona above the surface of the ancient sea, extending over part of the plateau and Colorado river region, past Prescott and on to Tombstone, Arizona. The main Arizona belt nearly coincides with the borders of the Paleozoic uplift.

The age of mountain uplifts we judge by the strata involved in that uplift, thus we know that the great uplift of the Rockies occurred at the close of the Cretaceous, because both the Cretaceous rocks and all those of previous ages are uptilted with the mountain while the Tertiary rocks are not.

These uplifts are not the immediate cause of mineral belts, but rather of fissuring and faulting.

The uplift in Nevada, at the close of the Carboniferous, was gentle without much crumpling of rocks, hence the number of ore deposits is not so great along its edge; those we do find, however, such as at Battle Mountain and Cerro Gordo, are on the edge of the uplift, and are rudiments of the belt, better defined in Arizona, where the uplift was more violent.

Thus there appears to be a relation between ore belts and lines of uplift, from which we may infer that the great Post-Cretaceous uplift of our Rockies determined some of the lines of our ore belts, and we shall find the line and time of uplift of some of the minor ranges in Colorado more or less coincident with the mineral belts found in them.

The uplift of a great range is not along a single line of dislocation, but such movements are accompanied by a great number of parallel faults, and parallel sets of fissures, with stringers running off into the surrounding region. A large belt of country is fractured by innumerable rents in many directions, which may afterwards be filled by veins, and constitute a mining district.

PRINCIPAL ORE-BEARING ROCKS.

In Colorado gold is found in the Archæan granites, gneisses, and schists, and also in the eruptive porphyries of Mesozoic or older age, and in the placer beds derived from these rocks.

In sedimentary formations, it is rare in limestone but occurs in quartzites of Silurian or Carboniferous age.

Silver is found in the Archæn and in the porphyries, and occurs especially in the limestones of Carboniferous age, as also in those of the Silurian, and locally in some of the Cretaceous Rocks.

The most important ore deposits are found where igneous eruptive rocks abound, especially in rocks of older date, as porphyries, rather than in the newer Tertiary volcanic rocks, such as basalts.

The "hogbacks" along the foothills consisting of upheaved limestones, clays, shales and sandstones yield no precious metals, and it is only when the mountains have been penetrated to their core that precious minerals are found productively.

The mineral deposits of Boulder are the nearest to the "hogbacks" and plains in this respect, some of the mineral belts being only two miles distant from the foothills.

Though the sedimentaries forming the "hogbacks," foothills and plains are not found productive, yet in the heart of the mountains where foldings, crumplings and volcanic eruptions have occurred, we find the same rocks quite prolific in minerals, notably in the Gunnison, South Park, Aspen and Leadville districts.

Part II.

COLORADO ORES AND THEIR MODES OF OCCURRENCE.

Metals occurring in a nearly pure state are called "native." Native gold in Colorado is sometimes visible to the eye in the form of little hairs or wires, or as minute grains or thin flakes upon a piece of ore, quartz or rusty material, but very rarely as nuggets in a vein. Nuggets, together with fine flakes of gold, are found in the gold placers. Native silver also occurs in little bunches of wires, and is sometimes called "wire silver." It is also visible as flakes or strings in vein matter. Native copper is occasionally found in thin plates in crevices of the rock. Metals united with non-metallic substances form "ores" proper. Most of our precious metals in Colorado are found in this condition. Metals unite with non-metallic bodies, as sulphur or chlorine, forming sulphides, (ex. gr. iron pyrites or galena,) or chlorides, such as horn silver; with oxygen, forming oxides, as oxide of iron or of manganese; with acids and salts producing carbonates, sulphates, etc., for example: carbonate of lead, (cerussite,) sulphate of lead, (anglesite,) carbonate of copper, (malachite,) carbonate of iron, (siderite.)

Any material containing a workable proportion of a metal is commonly called an "ore." For example, quartz carrying gold-bearing pyrites, or limestone containing silver-bearing galena. Ores are found in surface deposits, such as gold in placers, disseminated through igneous eruptive rocks, such as porphyries, also through sedimentary rocks, such as limestones, between stratified formations, such as between layers of quartzite, limestone, or gneiss, and in veins of different kinds, traversing all kinds of rocks.

The non-metalliferous and earthy minerals associated with the ore, such as quartz, calcspar, baryta, are called "matrix," "veinstone," or "gangue."

GEOLOGICAL OCCURRENCE.

Metals occur in Colorado in rocks of every geological age, principally in the mountainous districts and in the older rocks, especially at the junction of igneous eruptive rocks with sedimentary rocks.

The Archæan age is represented by the veins of Georgetown, Central and Boulder.

The Silurian and Carboniferous by the ore deposits of Leadville and South Park.

The Triassic by some copper stains in various localities, and a few lead deposits.

The Cretaceous by the veins of Crested Butte and Gunnison, and by iron-ore deposits.

The Tertiary by the veins in the Tertiary eruptive rocks of the San Juan region.

The Quaternary by the various placer deposits.

The Archæan, Silurian and Carboniferous, *i. e.*, the older rocks, are the great ore producers.

The plains and foothills yield no precious metals, only a few base ores such as iron. The precious metals are mostly confined to the heart of the mountains, and diminish in occurrence as we recede from it.

The ore deposits at Leadville occur at the junction of eruptive quartz porphyry with limestone. Those of Georgetown, Central and Boulder are also frequently found at the contact between porphyry and gneiss.

Metals also occur in sedimentary rocks which have been penetrated by dykes of eruptive rock, or have been exposed to great metamorphism. The Gunnison region around Crested Butte, Gothic and Irwin is a good example.

The marine Cretaceous sandstones and limestones and the Laramie Cretaceous coal strata have there been locally riddled by dykes and volcanic masses, which, besides throwing the region into strange contortions, have also, by their heat, metamorphosed it, changing limestone into marble, sandstone into quartzite, shales into slates, and coal into anthracite.

In this region veins of silver, lead and other ores are found, showing the striking connection between heat and its attendant metamorphism with vein occurrence.

ORES FAVORING PARTICULAR GEOLOGICAL HORIZONS.

Ores seem to favor some particular geological horizon, not because that particular geological age or horizon was one especially productive of mineral at the time of its formation, but rather that the rocks of that age happen by peculiar circumstances to be better adapted for receiving mineral solutions than those of some other ages. Thus the "blue limestone" of the Lower Carboniferous throughout our mountains has been particularly productive, not because it belonged to the Lower Carboniferous age so much as because it is locally penetrated by eruptive rocks, the limestone itself being favorable for receiving mineral deposits. Where the eruptive rocks do not occur the Carboniferous limestone is commonly as barren as other limestones generally are in Colorado.

GOLD PLACERS.

Gold is found in surface deposits of sand and pebbles resulting from the breaking up of older rocks by glaciers, and the distribution of the detritus by rivers, in what we call "placer ground." Among the pebbles and sand, gold is found in flakes and nuggets. The gold is derived partly from broken up gold-quartz veins in these older rocks or from the disintegration of the constituent minerals composing the mass of the rocks themselves, which contain minute particles of gold in their elements, particularly the igneous or metamorphic rocks, such as porphyries and granites. These placer deposits are of recent origin, dating from the Tertiary or Glacial Epochs to the present, and are to be found in nearly every mountain ravine in Colorado, or on the banks of our principal streams.

Those at Alma, (South Park,) along the Arkansas valley, and at San Miguel in the San Juan country may be cited as examples.

Platinum and tin are found under similar conditions, but these metals do not occur in Colorado.

NATURE'S MILLING PROCESS.

Gold quartz from a vein requires its gold to be artificially separated, first by crushing and next by water, the heavy metal sinking to the bottom, the lighter veinstone being carried off by water. In the case of placers which consist of boulders, pebbles and sand on the banks of streams or sides of canons, representing specimens of the varieties of rock over a large area, nature has already performed this process on a grand scale. The glaciers have mined and torn off the gold-bearing quartz of the veins together with cubic miles of rocky material, also holding minute portions of gold disseminated through it. The streams have reduced this to pebbles and sand, have mechanically separated the gold, and also probably by the action of acids chemically set it free from other minerals in which it was contained. By its gravity it sinks to the bottom and is found in greatest quantities next to the "bed rock" in cracks and crannies. The miner, after all this crushing, concentrating and jigging by nature, has only to re-wash and sift the debris and collect the water-worn flakes and fragments of free gold with or without the assistance of quicksilver.

CALIFORNIA PLACERS.

The vast placers of California lie for many square miles on the Pacific slope of the Sierra Nevada. They are called "blue gravels," and were brought from the range by glaciers and distributed over the more level country by ancient rivers and by lake-like expansions of such streams. The fossil remains of elephants and plants in them show them to date from the Tertiary or Quarternary age. Afterwards these river deposits were covered by volcanic ashes issuing from eruptions in the Sierras and finally by streams of lava from the same source. This hard molten crust upwards of one hundred feet thick, protected the underlying gravels from being washed away. Chemical changes in these gravels have silicified and changed to opal the once water-logged tree trunks brought down in these gravels. Some have been changed into lignite coal before silicification, part of the wood resembling jet, and part opal. The gravels are also cemented by silica.

Stone implements have been found under 100 feet of lava in the gravels, showing man's existence at the time the gravels were deposited. There are also several uncovered placers worked by hydraulics. Rivers flowing through the gold belt of California have acted as natural sluices of which the miner's sluice is a diminutive copy, the upturned slates acting as "riffles" to catch and retain the gold. The Australian placers are very similar to those of California.

COLORADO PLACERS.

The placers of Colorado have the same history, with the exception of the lava capping. The glaciers of the Glacial epoch and the floods resulting from their melting in the Quaternary epoch have been the main distributers of our placers. The gold is doubtless in part derived from gold-bearing quartz veins and gold-bearing rocks higher upon the mountains than the placer beds. Thus the placers of Clear Creek derive their gold from the veins and gold ore-bearing region around Central, Idaho Springs and Georgetown. The placers at Alma and Fairplay, South Park, from the veins and eruptive rocks near Mt. Lincoln and Montgomery, and the park ranges. The Tarryall placers in the basin of South Park from the auriferous deposits lately discovered in the eruptive rocks in the mountains above Breckenridge. The rich placers in "California gulch," now occupied by Leadville, and those widely distributed through the broad valley of the Arkansas, may have derived their gold largely from disseminations in the metamorphic granite and particularly in the eruptive porphyries, as gold veins have not so far been discovered in great abundance in that characteristically lead and silver bearing district.

COLORADO PLACERS DUE TO GLACIERS.

It is noteworthy that each of these localities shows unmistakable signs of former great glaciation. Clear Creek had its great glacier descending from Georgetown and joined at the forks of the creek by one coming down from Central. The whole valley in which Alma and Fairplay are located shows similar signs of a great glacier descending from back of Mt. Lincoln and receiving tributary glaciers from Mosquito, Buckskin and other canons. The basin of South Park was occupied by a glacial lake into which glaciers descended from the mountains around Breckenridge. The Arkansas valley was filled by a prodigious glacier receiving innumerable tributary glaciers from the canons of the Sawatch and from the slopes of the Mosquito Range.

Upon the moderation of temperature and consequent melting of these bodies of ice the Arkansas valley was occupied by a broad river, and "lake-like enlargements" of the same, which distributed the placer drift and gravel in banks and terraces over that area. That gold may be derived from the breaking up of igneous rocks seems probable from the "black sands" of the California sea-beaches which consist of titanic iron derived from the breaking up of the eruptive rocks of that volcanic region. These sands carry small nuggets and fine gold dust, the latter often too fine to save by present processes.

TIN.

Platinum and tin are found in other countries, but not in Colorado. Specimens of "stream tin" in dark brown, round nodules of the variety called "wood tin" showing a banded, jasper-like structure are found in the drift material in Durango, Old Mexico, but they have never been traced to any vein. So far as the geological relations are concerned there seems no reason why tin might not be found in the Archæan granite rocks of Colorado. In England it occurs associated with granite, porphyry dykes, slates and quartz veins. The English "stream works" are placers derived from these in the same way as our gold placers are derived from rocks originally "in place."

CHARACTERS OF GOLD IN PLACERS.

Nuggets of a large size are not common in gold veins, as they are in placers, yet they may exist in veins, for the largest American nugget, according to Newberry, was found in the vein of the Monumental mine at the Sierra Buttes, Downsville, California. It weighed ninety-five and a half pounds. Possibly in times long before man or mining, they may have been more common in the veins than now. And again, as our mining operations are but slight, they may be found hereafter.

Gold in placers is purer and of higher grade than that in veins, owing probably to its having been leached of its alloys by water and chemical action.

Silver we do not find usually in placers, it having been destroyed by water, but such insoluble substances as magnetite, titanic iron, garnets, rubies and even diamonds are found closely associated with gold in placers.

Gold is not wholly insoluble, but may be attacked by persalts of iron and salts of vegetation, so it may go through some chemical changes in placers, and some nuggets may be formed by concentration of gold in the placer itself. Nuggets of large size are, as a rule, found nearest the quartz veins which have supplied them, and the gold becomes finer as we recede from the source or from the mountain region. Pebbles of quartz containing gold are common in placers, showing the origin of the gold from a quartz vein, sometimes at least. Nuggets show on their surface the battering they have received in the stream.

CHARACTERISTICS OF PLACERS.

" Places where water currents were broken by a more moderate descent, sudden change of direction, or discharge of a side stream, are liable to receive gold deposits. Slight depressions, holes, open fissures or cracks in 'bed-rock' over which the current passed are often rich. The deepest layers near the bottom of the placer deposit or on the 'bed-rock' are generally richest. Periods of deposit may have followed one another and several rich layers lie one above another. Ancient as well as modern river channels may contain gold." The prevalence of a certain peculiar or characteristic pebble in a placer may enable one sometimes to trace the gold deposit back to the original locality whence the placer was principally derived and so lead to the original vein.

In some localities, especially where the " bed-rock " happens to be jointed sandstone or limestone, the gold may find its way for some little depth beneath the strata, and it becomes necessary to remove carefully a few feet of the bed-rock until a true " floor," such as an impervious layer of clay or other rock is found, below which experience proves the gold does not pass. The richest deposits of gold will often be found on that floor. The placer beds in Colorado consist of banks of pebbles of all sizes, mingled with some sand and gravel, showing little or rude signs of stratification. These beds are from 10 to 50, sometimes 100, feet thick and form a series of rolling or undulating banks along the sides of our canons, valleys or watercourses. Gold is found from the grass roots to the bottom of the deposit, but principally near the bottom, and especially on bed-rock. Assotiated with the gold, usually near the bottom of the bank, we often find a rusty sand containing pebbles of magnetite iron known as "black sand." This iron may have been derived from the original pyrites or "blossom" of the gold vein.

SURFACE DEPOSITS.—BOG IRON.

Of other surface deposits the commonest are those of bog iron, with which manganese oxide is sometimes associated. These beds, which are more or less impure, consist of hydrated peroxide of iron containing, when pure, 14.42 per cent. water. Phosphoric acid is sometimes present in quantity sufficient to diminish its value as an iron ore. Too much silica and other impurities may have the same effect. Bog iron ore frequently encloses the partially fossilized remains of roots of trees and swamp vegetation. The ore is the result of the chemical action of water, assisted by the acids of vegetation, upon minerals containing iron in another state, as upon iron pyrites and copper pyrites, as seen in the brown "gossan," "blossom" or "float" of the outcrop of veins. Iron-bearing minerals such as mica, hornblende, and augite, common in granite and eruptive rocks, contribute to these ores.

A deposit of bog iron ore is found near Crested Butte, in a swamp situated upon a terrace or drift at the base of a mountain. The original source of this iron is traceable to a vein of iron pyrites up the mountain slope. The drainage of the mountain has passed through this vein, leached out the iron from the pyrites, and redeposited it in an oxidized and hydrated state in the swamp. The acids of the marsh vegetation have assisted in this chemical change, and in the precipitation of the iron, which is found enclosing the roots of trees and grasses. The ore is remarkably good and pure. Its amount of Phosphoric acid is too high for Bessemer steel, but not for common pig iron. The amount of silica is very slight, while its percentage of peroxide of iron is very high.

Analysis by Prof. Chauvenet, of School of Mines:

Water and organic matter	23.97	per cent.
Silica	2.50	"
Peroxide of iron (iron, 50.73)	72.47	"
Alumina	0.28	"
Lime	0.22	"
Magnesia	0.12	"
Phosphoric acid	0.333	"
Phosphorus	0.145	"
Total	99.893	

IRON ORE IN COLORADO.

Iron ores, when they occur in metamorphic crystalline rocks such as granite, are in the state of ferric oxide (hematite), or magnetite. These ores are found in metamorphic rocks of Archæan and Paleozoic age.

Red hematite may be crystalline, fibrous, botryoidal, or compact. Magnetic iron ores containing much titanic acid are valueless. The magnetite from Grape Creek, near Silver Cliff, is an example. Fine-looking magnetites from several localities in Gunnison County are of no value, from their high per cent. of titanic acid. The black auriferous sands of California derived from the breaking up of eruptive rocks are titanic.

"Magnetite" was originally deposited by water solutions as a common hydrated iron or limonite, and by heat of metamorphism was crystallized like the surrounding rocks into magnetite, in this way losing its combined water.

In the oldest rocks, and especially the crystalline rocks, such as granites and porphyries, iron is a constituent of many of their component minerals, such as hornblende, garnet, mica, augite, etc. It is also the staining element in our feldspars, giving them their pink or red tint. In such rocks the ore is generally magnetite when in granite, and hematite when in schist. Much of the common limonite and iron oxide found in unaltered sedimentary sandstones along our foothills and plains was indirectly derived from these sources, for the elements of these unaltered sandstones consist of the detritus of granite and other older crystalline rocks when the sedimentary rocks were in the condition of gravel or soil. The magnetite and hematite in the granite minerals being exposed to water, were changed into hydrated ferric oxide. In this condition as a red coloring of the soil it was exposed to carbonic acid and the acids of vegetation, and was finally deposited as a common limonite, or as a carbonate of iron ("kidney iron stone.")

From observations in some of our iron veins in Colorado it would appear that iron pyrites is the original form from which by a secondary process, principally through surface action, magnetite and probably red hematite were derived, for we find magnetite on the surface passing down with depth into a vein of unaltered iron pyrites. "The process may be thus: iron pyrites under surface action has its iron and sulphur oxidized, and passes first into iron sulphate and thence into iron oxide. If heat or metamorphic action should now take place it is crystallized or changed into magnetite or red hematite."

As limonite and some carbonate of iron is so characteristic of the unaltered sedimentaries of our plains and foothills, and magnetite and hematite of our metamorphic rocks of the mountains, we might consider the latter as metamorphic iron. Magnetite is the best and leading ore of Colorado at present. From Prof. Chauvenet's reports we learn that—

"Iron is used for Bessemer pig iron, for steel and for common pig iron for foundry purposes.

The percentage of silica in an analysis should not exceed 10 per cent.

Phosphoric acid is found in nearly all iron ore. For Bessemer steel it should not exceed two-tenths of one per cent. (0.2 per cent.) For common pig iron not over four-tenths of one per cent.

The magnetites of Chaffee County, Colorado, are remarkable for their low per cent. of phosphorus.

Titanic acid, common in our magnetites, should not exceed 2 per cent.

Sulphur is deleterious to iron and usually occurs through the presence of more or less iron pyrites.

Manganese is a good adjunct, is not common in Colorado, except in the Gunnison region, but is associated with iron ore in the Leadville mines.

Water and organic matter, common in limonites and bog iron, can be easily gotten rid of. Much iron in the United States contains 8 to 10 per cent. water.

Lime and magnesia are good in moderation.

Iron ore should contain upwards of 50 per cent. metallic iron to be a good merchantable ore."

Along the foothills, beds of concretionary iron ore occur commonly above or below our coal seams of the Laramie cretaceous. It is generally a limonite running too low in iron and too high in silica and phosphorus to be of use. With few exceptions, so far we have discovered no promising iron beds along our plains or foothills.

At the Trinidad coal field several thick belts of concretionary iron ore occur above the coal seams under Fisher's Peak. The ore appears to be partially oxidized carbonate. Its analysis shows silica 9.19 per cent., protoxide of iron 45.04, lime 4.02, phosphoric acid 1.055, carbonic acid 33.035. Probably this is a type of other deposits along the coal strata of the foothills. "Such ore might be used for smelting common pig iron. Its phosphorus percentage is too high for steel, but it might be utilized as a mixing ore."

The marine dark shales of the Fort Benton group of the Cretaceous, that is Cretaceous No. 2, yield locally, near Morrison and elsewhere, some dark heavy concretions, whose percentage of iron, not over 22, is too low for use, and its silica being also high. It is to the mountain region we must turn for our great iron deposits. At Villa Grove we find irregular deposits of brown hematite in the metamorphic, Paleozoic limestone yielding 58 per cent. iron, with only 0.031 phosphorus and no titanic acid. This is a good Bessemer steel ore.

The Calumet mine in Chaffee County is one of the best in Colorado. It is a great vein 40 feet thick, traversing syenitic, crystalline rocks, and yields 63.28 per cent. iron, with only 0.016 phosphoric acid. It is largely used at the Bessemer Steel Works. In Park County, on Silverheels Mountain, near Breckenridge, a vein which produces excellent magnetite on the surface appears, with depth, to pass down into original iron pyrites, giving by analysis:

60.40 peroxide iron.
22.12 protoxide iron.
5.9 silica.

No phosphorus and no titanic acid. This vein appears to illustrate what we have said of pyrites being the original mineral from which magnetite is derived.

GUNNISON COUNTY IRON MINES.

Perhaps the heaviest deposits of magnetite yet found in Colorado are in Gunnison County. Of these the "Iron King," near White Pine, is the most striking, owing to its great outcrop and partial development. Since, however, a description of these deposits is found in the report of Prof. Chauvenet, (issued simultaneously with the present paper,) no details of occurrence or composition need be given here.

MINERAL STAINS.

Ores are sometimes disseminated through sedimentary rocks in which they have been chemically deposited.

Some of our Triassic red sandstones in South Park are locally stained green with carbonate of copper. The sandstones contain impressions of fossil leaves beautifully colored with this material, but no profitable deposits of copper have been found. Copper stains also impregnate the hornblendic gneiss near Golden, and on a line or belt at various points along the eastern flanks of the mountains. Occasionally flakes of native copper are found, but prospecting has developed no profitable deposits of copper ore.

Such blue and green stains of carbonate of copper frequently lead to the discovery of a true vein, containing copper or iron

pyrites at depth, from which the carbonate stains have been derived by surface action. Such stains are common in every mining district, associated with the surface indications or "float" of important veins or ore deposits.

ORE BEDS IN COLORADO.

"Ore beds are metalliferous deposits interstratified between sedimentary rocks of all geological ages." "They lie parallel to the planes of stratification and follow all the contortions of the enclosing strata, hence they are thrown into folds, troughs, arches, saddles, or basins. The upper portions of the arches may often have been removed by erosion, or the strata may be faulted." The ore deposits or beds at Aspen occupy a faulted synclinal fold or basin. The enclosing rock is limestone, in part dolomitic. At Leadville the deposits occupy part of a series of faulted anticlinal arches and synclinal troughs, of which the Mosquito range is the main axis. The beds lie between dolomitic limestone and sheets of porphyry. The ore beds partake of all the folding, faulting and other contortions which the enclosing rocks have suffered in the upheaval of the mountains.

The thickness of such deposits varies much and may gradually thin out and disappear, but may also continue long enough for all mining purposes.

Often there are no sharp limits between an ore bed and the enclosing rocks, or between the ore bed and the walls, if walls exist at all. The ore appears to impregnate the surrounding rock by a chemical interchange between the elements of the rock and the ore. Such a "metasomatic" interchange, "substitution," or "replacement" appears to have taken place in the argentiferous lead deposits of Leadville and Aspen between the ore and the limestones.

According to Phillips, "a true ore bed never produces a 'combed' or 'ribbon' structure made up of symmetrical layers such as is common in so-called 'true fissure veins,' and is usually without the crystalline texture observable in veinstones."

FAULTS.

Ore beds are subject to faulting, as at Leadville and Aspen. The common rule is that the footwall of the fault fissure usually rises or remains constant whilst the hanging wall falls down. When the opposite to this occurs it is called a "reversed fault."

The ends of the strata containing the bedded ore deposits on the footwall side of the fault fissure are commonly found bent downwards towards the fault as if dragged down by the fallen hanging wall side. In this case the ore deposit may be looked for below. The reverse, however, sometimes occurs.

A faulted region is one in which great folding or crumpling, due to horizontal, lateral or tangential pressure, has taken place, and where the folding has reached its utmost tension, the fold has broken, and a slip or fault is the result.

Thus in the South Park region adjacent to Leadville we find the horizontal strata of the Park as it approaches the Mosquito range becoming gently folded, the folds increasing in closeness and steepness the nearer they come to the range, until as we pass up Four-Mile canon, which gives a complete cross-section of the Mosquito range, we find the axis of the range to be formed by a magnificent and very steep arch, breaking down abruptly into the great London fault, which runs along and splits the axis of the range for twenty miles. Still further on in the direction of Leadville we pass over a series of parallel faults, each one representing a steep fold that once preceded the faulting. Faults have their points of greatest depth, and die out at either end, often in folds, this being well illustrated at Leadville. Great faults are accompanied by minor parallel faults, and also by cross faults intersecting them diagonally.

INDICATIONS OF FAULTING.

The surface indications of a fault are sometimes a "sag" or sudden depression in the outline of a hill. Thus from the Mosquito range we descend to Leadville by a series of steps or benches, each marked by a sag on the hill slope, the depression often constituting a little ravine filled by a water course and abundant vegetation.

In a mine such movements are indicated by slickensided or polished surfaces of the walls, or by a general broken up character of one wall or the other, due to the grinding of the walls in process of slipping. This grinding, as in the case of the great

Comstock mine, sometimes reduces quartz to a powder, like "commercial salt." The polished slickened sides often show groovings or striæ, indicating the direction of the slipping motion; such motion was probably slow or by short jerks, and may sometimes have been accompanied by earthquakes.

In a good section of a cliff, such as is sometimes afforded by a deep canon, by observing some well defined or peculiar stratum high up the face of the cliff, we may notice its position out of place further down and easily compute the amount of slip, but when slips or faults amout to thousands of feet of displacement it is only by an accurate knowledge of the original geological position of the displaced members that we can form an estimate of the amount of slip. For example, if the strata of a period such as the Silurian, whose geological position is near the base of the series, should abut against rocks of the Tertiary, whose position is near the top, we should conclude that a slip of many thousands of feet had occurred. We should know that the Silurian had risen many thousands of feet and that the Tertiary had fallen correspondingly, so as to bring these two widely distant periods on the same level. By observing somewhere else the thickness of the strata composing the periods intervening between the Silurian and the Tertiary we should form an estimate of the amount of slip.

On Castle Creek, near Aspen, the Mesozoic red strata, whose thickness numbers several thousands of feet, lies in the bed of the creek at the bottom of a lofty cliff of granite forming Aspen Mountain, upon the top of which rests the Silurian and Paleozoic. A great fault has therefore occurred by which the Paleozoic series has been lifted up and the Mesozoic series fallen down. The great fault fold of the Elk Mountains on Rock Creek in the same region, is another striking example of how intense folding passes gradually into profound faulting. The downward direction of the fault fissure is commonly slanting rather than vertical, it is not always regular, either; having sometimes a steeper dip in one place than in another, while its horizontal direction across the country is not always straight, but zigzag or curved. In a faulted district like Leadville there is generally a prevailing direction of up-throw or down-throw, thus at Leadville the up-throw is to the

East which is also generally the footwall of the fault fissure, whilst the hanging wall or western face of the crack has fallen. The greatest amount of slip in that district amounts to some thousands of feet, and that is near the center of the district. The slip diminishing North and South and dying out in folds represented by round hills.

The exact line of the fault fissure is generally obscured on the surface by crushed rock, debris and vegetation. In the mines, at depth we may find both walls wedged tightly together, and one side or both much crushed. Sometimes a little mineral may be found on the "cheeks" of the fault, dragged down from ore-bearing strata from above, or possibly leached from them and re-deposited. The fissure of the iron fault in the McKeon shaft is 3 feet wide in places, filled with broken rock and a dark clay. The cheeks are altered by surface waters impregnated with iron oxide, and what ore there is is water-worn, The fault plane has been exposed for several hundreds of feet by the McKeon shaft. The outcrop of the fault on the surface is irregular, its direction downwards, is steep, but accompanied at intervals by benches with rich deposits of ore on them. The main fault is accompanied by a series of smaller faults adjacent to it. From the movement of timbers, by 5° or over, in some of the mines adjacent to the fault plane it is suspected that the fault movement is still continuing. The same suspicious facts have been observed in the Centennial mine at Georgetown. Nor is this improbable, since we have evidence of comparatively recent elevation of the mountains in various parts of the Rocky Mountain system.

UNSTRATIFIED DEPOSITS, FISSURE VEINS, ETC.

Mineral veins are changeable in character, and their appearances of a perplexing and complicated nature. There is a gradual passage from one form to another, so that it is difficult to classify them. There is often no such sharp distinction between one form of ore deposit and another as legal disputes would sometimes demand, and a witness should hardly be called upon to assert on oath that such a vein is a "true fissure," or another a "bedded vein," or a third a "segregated vein." "Nature abhors straight lines" and sharp distinctions, and delights in blending one form imperceptibly with another.

Phillips divides veins into two classes, "regular and irregular veins." "Regular unstratified deposits include true veins, segregated veins, and gash veins." "Irregular deposits include impregnations, fahlbands, contact and chamber deposits."

Veins are collections of mineral matter, often closely related to but differing more or less in character from the enclosing country rock, usually in fissures formed in those rocks after the rocks had more or less consolidated.

All veins do not carry metals; some are merely barren quartz, feldspar, or calcspar, like the barren veins we so often see traversing granite or limestone rocks.

Veins may divide, "split up," or thin out, and are irregular in shape and structure, owing to the irregular width of the fissures and to other causes.

DEFINITION OF MINING TERMS.

The rock in which a vein is found is called the "country rock," *e. g.*, limestone, granite, porphyry.

The portions of country rock in direct contact with the vein are called respectively the "hanging wall," or roof, and the "foot wall," or floor. This is only in inclined or flat veins, as a vertical fissure vein can have neither roof nor floor, but only two walls, East and West, or North and South, according to the compass. The inclination of a vein to the horizon is its "dip." The horizontal direction of a vein at right angles to its dip is its "strike." The latter may commonly be observed along the surface outcrop, the former either in the workings of the mine or where the vein is exposed on the side of a canon.

Both dip and strike of a vein often vary much, the former with depth, the latter with extension across the country. A vein or ore deposit will not unfrequently begin with a gentle dip, and increase rapidly in steepness with depth. The ore deposits on Aspen Mountain commonly begin with a dip of 25°, and at a depth of less than a thousand feet reach 60° or more.

As fissure veins commonly occupy fault fissures, their irregularities in dip and strike correspond to those we have already spoken about, under faults.

The angle of dip is usually taken from its variation from a horizontal, not from a perpendicular line. Thus a dip of 75 degrees means one that is very steep, while one of 10 degrees is a gentle inclination.

A layer or sheet of clay called "gouge" or selvage often lines one or both walls of a vein between the country rock and the gangue or vein proper. It is derived from the elements of the adjacent country rock decomposed by water, and sometimes by the friction of the walls of the fissure against one another, or against the vein matter, in the process of slipping and faulting, which is often shown by its being smoothed, "slickensided," polished or grooved. Gouge often contains some rich decomposed mineral in it, such as sulphurets of silver. It sometimes occurs in the heart of a vein, especially if that vein has been re-opened anew by movements of the strata. The "Chinese tallow" gouge of Leadville results from the decomposition of the feldspars in the adjacent white porphyry and is a hydrous silicate of alumina.

In the granite veins in Clear Creek County the gouge is derived from the feldspars of the granite. Gouge is sometimes useful in defining the limit of the vein between walls, thus preventing unprofitable exploration into the "country." It is also a guide for following down a vein when mineral and gangue may be wanting or obscure.

Both walls are not always clearly defined by slickensided surfaces, by gouge or other mark, and so at times the vein is lost.

False walls, caused by movements in the adjacent strata, by joints, etc., also mislead.

It is not uncommon in Colorado for a fissure vein to have but one clearly defined wall, the other, if it exists, being obscured or changed by mineral solutions. Sometimes two cracks or fissures occur parallel to each other and the intervening country rock has been altered and mineralized into a vein. It is probably in this way that many wide veins were formed.

Mr. Emmons has found that fissures are formed by great movements of the earth's crust or by local contraction of the rocks. That a fissure is not necessarily one with well defined walls, at considerable distances apart, filled after the formation of the fissure, but that the ordinary cracks or joints in granite quarries extending regularly to great lengths or depths illustrate the original fissures which have been changed by percolating waters carrying mineral solutions, into veins and deposits of ore. In all crystalline and sedimentary rocks these cracks or joints run parallel to each other at various distances apart, often plentiful and close together. In cases where percolating waters were charged with the proper metals and veinstone matter and the necessary chemical and physical conditions existed, the rocks lying between those cracks or joints were altered into ore.

As one element was dissolved another took its place, so according to this authority it would seem that even a fissure vein may be only a sort of "metasomatic replacement" of rock by mineral. Hence what is commonly accepted as a "wall" of a vein is not necessarily one, and cross-cutting, in order to determine the lateral boundaries of the ore, is safer than to rely on supposed walls. A so called "slip" has often been followed by a miner as a supposed wall, until by accident he broke through and found good ore on the other side. If veins are formed according to Mr. Emmons' theory, the occasional loss of one or both walls is easily accounted for.

Cross veins of a more recent age sometimes cut or fault an older vein. The point of intersection is generally rich in mineral. Cross veins must not be confounded with "leaders," which are the filling of minor cracks extending off from the vein, and are sometimes sufficiently profitable to work. While they sometimes lead a prospector to the main vein, they may also lead a miner under ground astray from the true vein.

The splitting of a vein by a "horse" or large fragment of the country lying in the vein may be mistaken for a true cross vein, or the original fracture of the fissure may have been in the form of a star or like the spokes of a wheel radiating to the hub. In such cases there are no true cross veins. But when, as in the San Juan district, we have two well defined sets of veins, one striking North East by South West, and the other North West by South East, they cut each other diagonally, the cut vein being the older. These opposite sets of veins have been formed at different times. Many contain a characteristically different class or variety of minerals. Thus in Cornwall, England, one set carries tin and the other lead.

SIGNS OF A TRUE FISSURE VEIN.

True fissure veins show signs of motion or slipping on the sides of the fissure, such as slickensides, gouge, crushed walls, "horses," or "breccia," the latter being small portions of the country rock fallen into the vein and cemented by vein matter. In the Comstock, the quartz is ground to powder. The vein itself, though occupying a healed fault fissure, may be itself faulted by later movements in the mountain after the vein was formed. Some of the fissure veins on Engineer Mountain, San Juan, are so dislocated.

The vein-filled fissures being a line of weakness, may be re-opened by mountain movements, and other or different combinations of ore introduced into the heart of the vein. Such a re-opening would be marked by a succession of "combs" or banded ribbon-like deposits of ore, and by gouge matter.

OUTCROP OF VEINS.

The outcrop of a vein is that which appears at the surface and usually attracts prospectors to the spot. Sometimes it may be, as in the San Juan district, a bold vein of hard white or rusty quartz, standing up in relief, by its superior hardness, above the surrounding country, like a low wall. Or again, in the same district, from being composed of softer or more soluble substances than the prevailing eruptive lava sheets, instead of a wall it causes a depression or trough on the side of a hill forming the pathway for a rivulet and marked by luxuriant vegetation. Commonly the outcrop consists of a decomposed mass of rock stained with oxide of iron and streaked here and there with green or blue carbonate of copper, and is called "float" or "blossom" by the miners. This "float" is the chemically changed or oxidized portion of the true and unchanged vein lying deeper below the soil.

In this "blossom rock" free gold is not unfrequently found, but unaltered sulphides, such as galena or iron pyrites, are rarely met with on the outcrop. In the San Juan district, on Mineral Point, we have, however, found galena at the grass roots, and broken off large chunks of it from a quartz vein outcropping on the surface.

In gold-bearing veins such an oxidized condition is desirable if it continue down to any depth, for so far as it continues the gold is free, and the ore is a free milling one, easily treated, and often exceedingly rich in gold, as in the celebrated Bowen mine of Del Norte; but as soon as the hard white quartz and the unoxidized pyrites of the true vein is reached, the ore is no longer free milling, but must be smelted. The gold may still be found free, perhaps, in the hard quartz, but if the pyrites should not prove rich in gold, the palmy days of the mine may be considered as past. Many such rich deposits on the surface, abounding with specimens of free gold, have proved great disappointments with depth.

WIDTH OF VEINS.

Veins may vary in width or thickness from a half inch to a hundred feet. They also pinch or widen at intervals in their downward course. The widest "mother" veins are not always the most productive, though they are very persistent in length, and we may suppose in depth also. In the San Juan district the "mammoth" veins of quartz, often a hundred feet wide, are not the favorites for development, the ore being found too much scattered in them, and the development less easy than in those 10, 20, or 30 feet wide, where the metal is more concentrated. These mammoth veins in the San Juan are easily traceable for miles over the surface of the country and down the sides of the deep canons. Their limiting depth has never been reached, and probably never will be by mining.

DEFINITION OF TRUE FISSURE VEINS.

True fissure veins are popularly defined as filling fissures of indefinite length and depth, commonly occurring in parallel systems, traversing the surrounding rocks independently of their structure or stratification, and commonly, though not necessarily, at an angle different from that of the stratification — in other words, cutting across the planes of stratification. These veins originated in fissures, not necessarily wide open ones, but on the contrary, rather narrow cracks, descending, however, to great depth such as those produced by faulting, or the general cleavage lines of the mountain. The latter may be frequently observed in every canon, and also in the sedimentary rocks of the foothills and even along the flat surfaces of the plains. They are very conspicuous in the plains around Trinidad, and are there not unfrequently occupied by a series of narrow parallel dykes of basalt instead of by mineral veins. Cleavage lines or joints are familiar to every stone-quarry man.

These cracks are caused by extensive movements of the earth's crust in the process of mountain uplift, and also on a smaller scale by contraction of the rocks in cooling from a heated or molten condition, or even in consolidating from a soft or muddy condition.

The two walls enclosing a vein do not generally coincide, as might be expected, since the vein occupies a line of fault. A true fissure vein may in some part of its course coincide with the dip of the surrounding strata. As the plane of stratification or line of division between one stratum and another is a natural line of weakness, a crack once started would be liable to follow it for some distance. And when uplift occurs such places are liable to slip one upon the other and a true parting fissure ensue, conformable to the prevailing dip. Such a vein might appear at first to belong to the class of so-called "bedded veins," but if with depth it should be discovered to be cutting across the strata it would be pronounced a true fissure vein. The appearance of slickensides or other signs of motion on the walls of the apparently "bedded portion" would then prove it to belong to the "true fissure" class and that actual fissuring had taken place prior to the vein-filling.

CAUSE OF POCKETS IN FISSURE VEINS.

As a fault fissure in its downward course usually pursues a zigzag rather than a straight course with smooth surfaces on either side of the crack, the inequalities of one face of the crack are brought into opposition to the inequalities on the other face as one or the other side of the fault slips up or down, and thus are produced pinches and wide cavities, which give rise to the "pinches" and "bonanza," "pockets" so common in fissure veins.

A so-called true fissure vein may sometimes have advantages over some other forms of vein occurrence, from its persistency and comparative regularity to great depths. It must not, however, be expected that it will continue equally rich or equally poor throughout its course. There may be comparatively barren spots and rich spots, pinches and widenings, local combinations of richer or poorer varieties of mineral. But the vein as a rule is not likely to entirely give out.

RICHNESS WITH DEPTH.

There is no scientific reason why a vein should "grow in richness and size with depth." This is a popular fallacy, originating from the now less accepted theory that veins were formed by the precipitation of precious metals by heated rising waters or vapors, and hence that the greater concentration would take place at greater depths. The "lateral secretion" theory now commonly accepted ascribes the deposition of ore to solvent waters reaching the vein from ground quite near to it and coming naturally from above and the sides quite as often as it is ejected upward by pressure from below.

In Idaho Territory, says Mr. A. Williams, "the rule is rather that veins grow less rich and strong with depth, though strong veins may continue metalliferous to a greater depth than mining can ever be reached."

"The thickness of the earth's crust which we are able to explore is very limited. Increase of heat, as in the deep Comstock mine, and other natural difficulties, limit us to a few thousand feet—3,000 at most. These deep mines have not, as a rule, proved richer with depth, but to the contrary. Some veins have been worked through alternate zones of richness and barrenness. The Comstock, which has been opened for four miles in length and to a depth of 3,000 feet, shows the ore bodies to be scattered irregularly and the barrenest ground is as the bottom. On the other hand some of the most celebrated mines derived their wealth from rich ores encountered near the surface and have proved most disappointing with depth."

Atmospheric action for a long period has often reduced the ore to its richest compound, and when the hard material is reached, leanness sets in. This, as we have observed, is commonly the case with gold veins. The richness of the Leadville mines is derived from their decomposed compounds. Again, as the surface crust can be so little explored by mining, it is to be remembered that the erosion by glaciers and waters has already removed thousands of feet of the vein, so that we are able to examine only a small fraction of it while an unknown quantity lies in the depths below. If these veins, then, continue to the supposed great depths below, we are very far from their starting point, and erosion having removed their upper portions, we cannot find their surface finishing point; in other words, it is not a fresh "ready made" vein we find, but portions of an old vein already extensively mined by the processes of nature.

So far as our experience goes in Colorado, after a moderate depth is reached below surface action, or below the "water level," a fissure vein may grow richer or poorer, wider or narrower with depth, without any law except local experience in a district.

VEINS IN GROUPS.

Fissure veins occur in clusters and nearly parallel groups, forming a mining district, and again in that district certain peculiar veins may be grouped together, forming a "belt." Thus Boulder district occupies a certain isolated area, outside of which few mineral deposits occur for a long distance. We have also in that district several distinct belts carrying different characteristic ores, such as the telluride belt, marked by rare telluride deposits, the pyritiferous gold-bearing belt, and the argentiferous galena belt. The Central City region is characterized by auriferous pyrites belts, Georgetown district, not far distant, by argentiferous belts, and Idaho Springs, lying between the two, by both gold and silver belts.

RELATION OF VEINS TO ERUPTIVE FORCES.

The ultimate cause of the richness in veins of a district or locality is, that local dynamic and eruptive forces were more energetic there than elswhere, causing great disturbance of the rocks accompanied by fissures, and eruptions of porphyry.

Thus at Leadville the Mosquito range is violently folded and fractured, eruptive rocks have issued abundantly, and associated with such phenomena we find great lead and silver deposits.

Further South the great San Juan district is split up in an extraordinary manner with great fissure veins. The region is an eruptive one, consisting of prodigious flows of porphyry or eruptive rocks traversed, not unfrequently, by newer eruptive dykes.

In the Gunnison district the strata have been overturned, disturbed, folded and faulted in an extraordinary manner by the intrusion of great masses of eruptive rock forming the peaks of the Elk Mountains. The strata every where are riddled by dykes or intrusive sheets, and the evidence of heat is apparent in the general metamorphism of the entire region. Mineral veins abound. The same phenomena are repeated more or less in the neighboring region around Aspen, at Pitkin, and at Tincup.

At Boulder, Central and Georgetown there is a concentration of eruptive dykes locally in each district and few dykes or eruptive rocks outside of those districts. On the other hand we have no ore deposits in the undisturbed rocks of the plains or the flat basins of our parks, and notably our mining districts are for the most part well in to the core of the mountains, where, in the nature of things, folding, crumpling, faulting, eruptions and metamorphic heat were more energetic than along the flanks and foothills of the range which have usually proved unproductive.

The older eruptive rocks such as the quartz, porphyries and diorites of the Leadville, South Park and Gunnison districts, are more favorable to the production of ore deposits as a rule, than the more modernly erupted lavas, such as basalt or dolerite which we commonly find occuring in dykes and surface overflows traversing or capping our Cretaceous and Tertiary coal fields along the foothills as at the Table Mountains at Golden and Trinidad.

Some of the lighter colored and somewhat recent lavas like the tufaceous rhyolite, which caps so many of the Tertiary mesas on the divide between Denver and Colorado Springs have also hitherto proved barren. The older eruptive rocks, as we have stated, are nearly all of an intrusive character, never having reached the surface, while the newer ones bear evidence of having flowed over the country like modern lava streams, as is shown by spongy scoria on their surface, and may be called "extrusive."

In Colorado the ore body is not usually found in the heart of an eruptive sheet or dyke of porphyry, but at the line of its contact with some other rock, such as limestone, granite or gneiss.

CONTACT DEPOSITS.

The "contact" ore deposits of Leadville occur at the contact of quartz, porphyry and dolomitic blue limestone.

Some of the veins at Boulder, Central and Georgetown are at the contact of porphyry and granite or gneiss.

Exceptions occur, however, where mineral is found either in the heart of a dyke, or the whole dyke may be so impregnated as to constitute in a sense a vein. These exceptions are generally confined to pyritiferous gold deposits.

GOLD-BEARING DYKES.

Suppose a dyke or mass of eruptive rock to be thoroughly impregnated with gold-bearing pyrites. Near the surface and often for a considerable depth the rock is decomposed and the pyrites oxidized into rusty iron ore, liberating the gold which is entangled in the "gossan" in wires, flakes or even small nuggets. As long as this decomposed or oxidized state continues, the ore is free milling, but with depth the dyke is found in its primitive hardness, studded with iron pyrites which may or may not prove rich enough for the more expensive treatment of smelting. Such gold-bearing dykes are found at Breckenridge, South Park, also in Idaho Territory and in old Mexico, and many other gold-bearing regions.

The Printer Boy gold mine at Leadville is a vertical deposit in a jointing or fracture plane in a dyke of quartz-porphyry, rusty and much decomposed near the surface, where it yielded free gold; with depth this passes into copper and iron pyrites. The vein is from an inch to four feet in width, stringers carrying ore extend into the porphyry, which is highly charged with pyrites which doubtless supplied the vein with mineral through the agency of surface waters. In Arizona, near Prescott, at the Lion mine we find a green dyke of eruptive diorite penetrating granite. This dyke is traversed by numerous small veins of white quartz which near the decomposed and rusty surface are rich in free gold. At a slight depth the quartz veins become charged with unoxidized iron pyrites sufficiently rich in gold to merit treatment by smelting. The surface ore is treated by a simple "arrastre," and is, of course, free milling. The gold seems to be mostly confined to the quartz veins.

FISSURE VEINS IN IGNEOUS AND GRANITE ROCKS.

The San Juan district is an exceptional case where immense numbers of fissure veins penetrate igneous eruptive sheets. The fissure veins consist of hard gray jaspery quartz, traversing lava sheets whose united thickness is from 2,000 to 3,000 feet. The veins produce lead, bismuthinite, gray copper and other silver-bearing ores.

In Colorado true fissure veins are most characteristic of the Archæan granitic series. In fact, all the veins in that series are fissure veins. Locally they occur as in the San Juan, cutting through eruptive rocks. Outside of these formations few true fissure veins occur.

An exception may be made of the Gunnison and Elk Mountain region where the fissures traverse all the formation from Archæan granite to the top of the Cretaceous coal beds. Nearly all other mineral occurrences, such as those in the limestone regions, come under the class of bedded-veins or blanket-veins, pipe-veins or "pockets" and show none of the characteristics of slipping motion or fissure action. Under this latter class the Leadville and Aspen deposits may be grouped.

Ore deposits commonly occur at the junction or contact of two dissimilar rocks, as between quartzite and limestone or limestone and dolomite.

Lodes occur also between the stratification planes of the same class of rock, sandwiched in between two layers of limestone, and sometimes impregnating the layers on either side for some distance from the dividing line between the two stratas, which is commonly the line of principal concentration of ore, and often descend from this concentration line, through the medium of cross joints, to form large pockets in the mass of the limestone. The Aspen and Leadville deposits are of this character. Also when ore bodies occupy a true fissure *i. e.* one cutting across the stratification planes, they may locally, for a short distance, impregnate the adjacent walls or country rock more or less. Our fissure veins in granite and gneiss often impregnate the walls to a small extent.

Mineral deposits favor as a rule the older rocks, such as the Archæan and Paleozoic series, probably because heat and metamorphic action are commoner in these older rocks, which have felt all the throes of the earth from past to present times, than in the more recent ones, and such circumstances, as we have stated, are peculiarly favorable to vein formation and mineral deposition.

The bulk of our precious minerals in Colorado come from the older Archæan and Paleozoic series of rocks, the exception being the Gunnison region around Crested Butte, Irwin and Ruby, where ore comes from fissure veins in the Mesozoic Cretaceous rocks. The exception is accounted for by the local metamorphism, heat and eruptive phenomena of that region.

The veins in the San Juan have also been ascribed by some to the Tertiary period, owing to their occurrence in certain supposed Tertiary lavas covering that district.

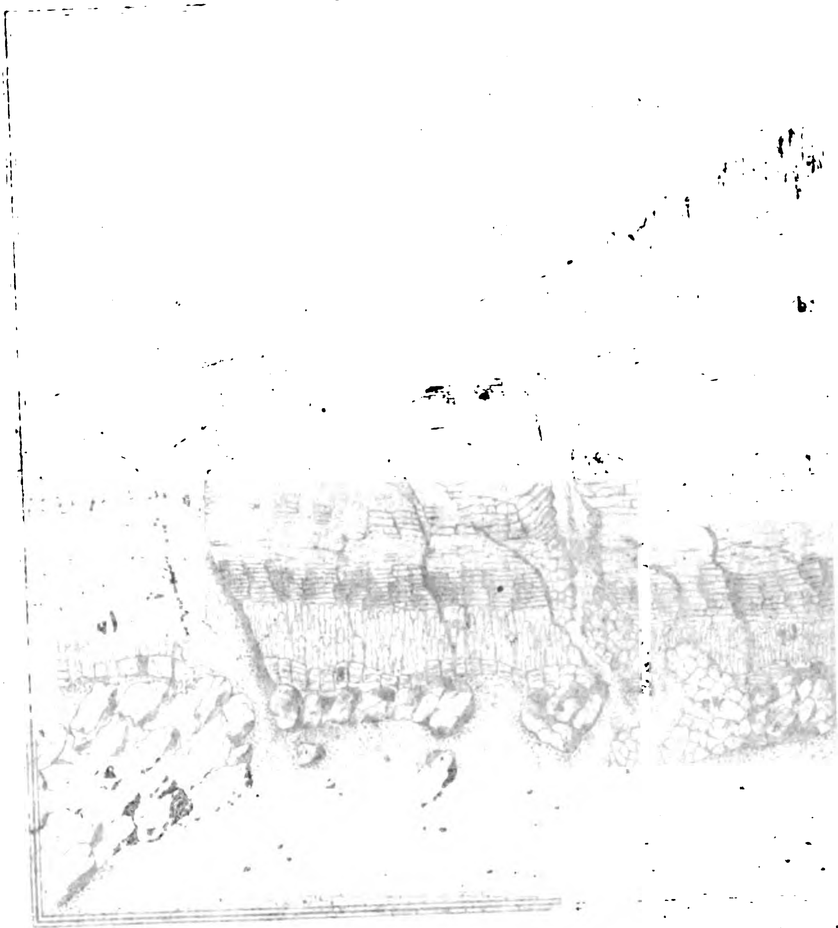
Besides heat, metamorphism, dynamical disturbances and eruptive agencies, other minor circumstances may favor ore deposition. Certain rocks, such as limestones, may offer by their tendency to solubility and chemical reactions, more favorable conditions than others for mineral solutions to deposit by "metasomatic" interchange between mineral and limestone, until the limestone is gradually replaced by ore, much in the same way as the elements of a water-logged trunk of a tree are replaced by silica in the process of fossilization.

DESCRIPTION OF ERUPTIVE ROCKS.

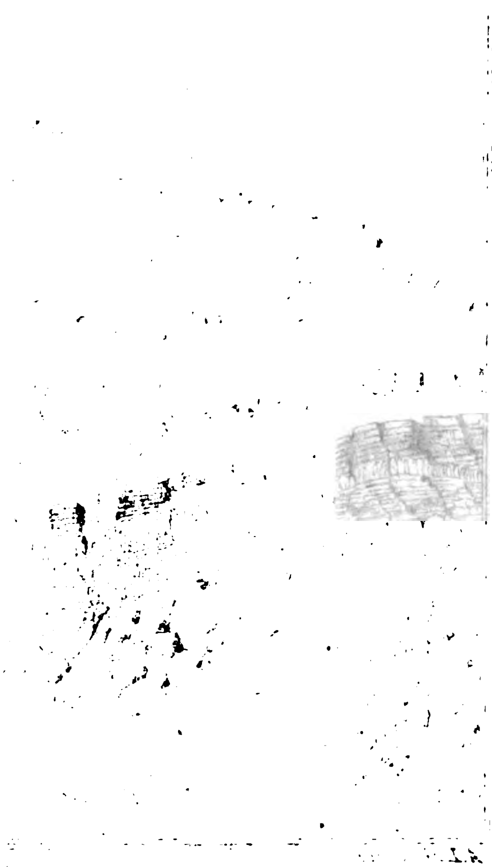
As eruptive igneous rocks commonly called "porphyries" play so important a part in connection with ore deposits, it will be well to give such a general description of them as will enable a miner to recognize and distinguish them in the field.

They differ from ordinary sedimentary rocks, such as sandstones and limestones, in their origin, mode of occurrence, structure and appearance.

Their origin is that of fire, not of water. They have been thoroughly fused and melted in the bowels of the earth. They occur erupted through fissures, piercing both the foundation



[illegible] Lower Carboniferous Limestone; (p) [illegible] Porphyry. [illegible] Porphyry



granite and overlying quartzites, limestones or sandstones, prying open the leaves of the sedimentary strata, and forcing their way in between the strata in horizontal sheets, arching up the strata and faulting them and filling the space they have opened with a thick, dome-like, lenticular mass of porphyry sometimes 1,000 feet thick, called by geologists a Laccolite, which ultimately thins out either way in a sheet terminating in a wedge between the strata, showing their eruptive intrusive character and their igneous origin. The internal structure of these rocks is thoroughly crystalline, as distinct from those of sedimentary aqueous origin. The latter show either to the naked eye or under the microscope that they are made up of more or less water-worn fragments of other rocks.

The eruptive rocks are of course unfossilliferous by reason of their igneous origin. They are, as a rule, harder than most of the sedimentary rocks and will not generally split up into lamina like shale, slates, or some sandstones. There is no "way of the grain" to them as there is in those of aqueous origin. They break like cast iron or other crystalline substances, and both on the surface and fracture show their distinctly crystalline character.

CHARACTERISTICS OF PORPHYRIES.

The component minerals of these intrusive porphyries are principally quartz and feldspar, together with mica or hornblende.

In color, these rocks are commonly some shade of gray or green, maroon, or even white, but their most striking characteristic is a general spotted appearance. This arises from large perfect crystals of quartz or feldspar being set in a finer-grained crystalline paste or background, and standing out prominently from it. This base or background may be comparatively coarsely crystalline, finely crystalline, or so finely crystalline that the crystals can only be discovered by the microscope, and the larger crystals of feldspar seem set in the paste, like plums in a pudding. In the depths of a mine the porphyry is commonly much decomposed, and even passes into "gouge" or clay matter. Its spotty character, from the presence of individual feldspar crystals, even then may identify it at times, or the aluminous character of the decomposed rock may be sufficient.

When feldspar is the main constituent it is called a felsite-porphyry. When a certain amount of quartz is observable, a quartz-porphyry.

Diorite also belongs to this intrusive eruptive class, differing mainly in the fact that its feldspar is plagioclase instead of orthoclase. Hornblende is generally a prominent constituent, and gives it commonly a more or less dark green or greenish hue. In appearance it is not unlike common granite or syenite, but its eruptive occurrence distinguishes it at once from them.

The main peaks and dome-like masses of the Elk Mountains are principally diorite, which in old reports used to be called "eruptive granite." It is generally finer grained than the common quartz porphyries. From the dark olive green that it assumes when weathered it has been called "greenstone."

MODE OF OCCURRENCE OF QUARTZ PORPHYRIES IN SOUTH PARK.

Quartz porphyries are among the commonest varieties of intrusive eruptive rocks in the mining districts of Colorado. The eruptive rocks of the Leadville and South Park districts are principally quartz porphyries. In almost any canon in the Mosquito range between South Park and Leadville we get a section of a thousand feet or more of different rocks, and we see the canon cliffs to be composed at the base of granite and gneiss, upon which rests, at a slight angle, a great thickness of sedimentary beds. These are principally quartzites and limestones. Passing up through the granite, we may notice a dyke of quartz porphyry, which perhaps when it enters the sedimentaries, opens them up between their strata and intrudes itself in a mass, gradually running out at either end. The dark green or gray color of the eruptive rock, together with its columnar structure, readily distinguishes it from the sedimentary beds. Sometimes a great "laccolitic" mass is so formed between the strata, which are arched up and faulted. At other times the eruptive sheets look almost like interstratified rocks, so well do they conform to the strata. Its intrusive character, however, is very apparent by its tendency to cut across from one set of strata to another. The feeding dyke or vent of this porphyry may not be seen always attached to its laccolite, sheet or branches, but may be found perhaps miles away as a dyke coming up through granite from the top of which the sedimentary rocks, together with their included intrusive sheet, may have been entirely eroded off, and we have to look for the porphyry sheet elsewhere. Sometimes, again, we may find the great laccolite entirely denuded of the strata which once arched over it, and it may constitute, as in the case of the principal peaks in the Elk Mountains, a prominent peak or dome of eruptive rock. Crested Butte Mountain, Gothic Mountain, both of quartz porphyry, and White-rock and Snow-mass Mountains, of diorite, belong to this laccolitic type—reservoirs of congealed eruptive rock, revealed by the denudation of thousands of feet of sedimentary rock, that once arched over and lay above them. Whenever these porphyries or diorites are found in Colorado their presence implies that great denudation has occurred, uncovering these deep-seated subterranean reservoirs of molten rock, for, as we said, they are all intrusive sheets. None of them ever flowed out over the surface, but they came up from depths unknown, and not having eruptive energy enough to penetrate to the surface of the earth, they spread out and congealed beneath that surface, forcing their way into any local weakness among the adjacent strata.

A dyke not unfrequently is the cause of the existence of a prominent mountain peak. Thus Mount Lincoln over 14,000 feet above the sea, owes its prominent character to a dyke of quartz-porphyry which has come up through the granite and sent out intrusive sheets between the overlying quartzites and limestones binding the mountain mass together as by a tree with locking branches and so preserving it from the general erosion as a noble monument of fire and water. These eruptions appear to have occurred at different times, as we frequently meet older intrusive sheets cut by dykes and intrusive sheets of a newer and a different variety of porphyry. The eruptions in the South Park region seem to have occurred till near the close of the Mesozoic epoch, as these dykes and sheets are found in rocks of that epoch as well as penetrating the older Archæan and Paleozoic series.

The eruptive rocks we have mentioned are those most commonly associated with our ore deposits, but there is another and apparently more recent class less commonly associated with ore deposits in this State; these are,

YOUNGER EXTRUSIVE IGNEOUS ROCKS.

Their leading characteristic is that they have reached the surface and flowed over it like modern lavas and may be called extrusive rather than intrusive. Typical of these we may cite the dark dolerites and basalts that cap our coal fields and Tertiary and Cretaceous strata along our foothills, frequently forming mesas or table lands by their protecting cap of lava, or appearing in steep ridges or sharp conical hills called "buttes" where their dykes only are exposed. The andesite forming Buffalo Peaks, South Park and the tufaceous pink rhyolite capping the Tertiary mesas on the divide between Sedalia and Colorado Springs, so much used for building stone, and the rhyolites of Nathrop and Chalk Mountain, Kokomo, belong to this extrusive or more modern type of igneous rock.

The colors of these rocks are either very dark gray or black, or very light, and even white. In the one case they consist of dark, heavy minerals such as augite, magnetite and feldspar and are said to be basic. In the other, principally of light minerals, such as feldspar and quartz, with a sprinkling of mica or perhaps a little hornblende and are called acidic.

The lighter rocks are popularly and erroneously called "trachytes." They are mostly rhyolites, as trachyte is a very scarce rock in Colorado or in these mountains generally.

At Nathrop station near Buena Vista and Chalk Mountain, Kokomo, and Black Mountain, South Park, are good examples of rhyolites. The great eruptive region of the San Juan appears to consist of quartz-porphyries, diorites, porphyrites, some andesite, rhyolites and basalts so far as we at present know, and there appears to be an older and a newer series of igneous rocks in that region.

TYPICAL PORPHYRIES AND ERUPTIVE ROCKS DESCRIBED.

Though there are a great variety of eruptive igneous rocks distinguished from one another by many hard names and subtle definitions, the ordinary mining man need concern himself with but a very few characteristic types commonly met with near the ore deposits of Colorado. We will mention some of these and roughly define them.

They are quartz-porphyries, porphyrites and diorites.

A quartz-porphyry is a porphyry that contains quartz crystals, large or small, in addition usually to very large crystals of orthoclase feldspar, generally of a vitreous or glassy variety called "Sanidin," together with small crystals of hornblende or mica. We will take that which forms the dyke on Mt. Lincoln, South Park, as a type. It is called Mt. Lincoln quartz-porphyry.

In appearance it is a gray rock, spotted with large crystals of orthoclase sanidin feldspar, which sometimes shows an oblong face two inches long by nearly an inch wide, at other times a shape like the gable end of a house, according to which part of the crystal is exposed. Sometimes two crystals are seen locked together, forming what are called Carlsbad twins. When the rock is decomposed these crystals not unfrequently fall out, and lie as pebbles on the ground. With these may also be seen the ends of bluish or pinkish crystals like broken glass. These are portions of quartz crystals which, when extracted perfect from the rock, show a six-sided pyramid at either end. These large crystals are set in a crystalline paste of smaller crystals of the same kind, together with many little black cubes of shining mica or duller lustred and longer rectangular oblong crystals of hornblende.

This porphyry is eruptive and intrusive, occurring in dykes and intrusive sheets and laccolites. In the South Park region around Mt. Lincoln, and in the Gunnison region, around Crested Butte and Gothic, it is exceedingly common, as well as in many other localities in Colorado. In Leadville there are several varieties of much the same class of rock.

LEADVILLE WHITE PORPHYRY.

At Leadville there is a quartz-porphyry known as the Leadville white porphyry, or "block porphyry," by the miners, which needs description, as it is the one that commonly overlies the rich ore deposits. It is a white compact homogeneous looking rock not unlike a shaly white sandstone, limestone or quartzite.

It consists of feldspar, quartz and a little mica. Its porphyritic or spotted character is so indistinct that one would hesitate to call it at sight a porphyry, but the microscope reveals perfect double pyramids of quartz and perfect individual crystals of feldspar set in a paste of the same minerals. It is often stained by concentric rings of iron oxide and marked with wonderful imitations of trees. The latter have earned for it the title of "photographic rock." These markings are only the crystallization forms of oxide of iron or manganese, something after the manner of fern frost work on a window pane, and are called "dendrite." or tree rock. This porphyry is very shaley and breaks off into thin blocks, hence its name locally of "block porphyry." It is an eruptive, intrusive rock occurring in dykes, laccolites and intrusive sheets. It is common at Leadville, but not so much so in other parts of Colorado. There are several other quartz porphyries akin to these, such as the gray porphyry, the Sacramento porphyry and the pyritiferous porphyry. The latter is so named from its being everywhere highly charged with minute particles of iron pyrites. It is not improbable that a good deal of the gold of this region came indirectly from this porphyry.

PORPHYRITE AND DIORITE.

These two rocks are so nearly alike in their mineral composition, mode of occurrence and appearance that we class them here as one. They differ from quartz-porphyries mainly in the fact that their feldspars belong to the plagioclase instead of the orthoclase variety. Hornblende also is a main constituent of these rocks and gives them their general dark gray or greenish tint. The appearance of diorite is not unlike that of granite or syenite, but its mode of occurrence as an eruptive, intrusive rock distinguishes it from the latter. Quartz is also present, so their general composition may be plagioclase—feldspar, quartz and hornblende. Mica, too, may or may not be present. A porphyrite appears to be little more than a porphyritic or spotted diorite. The plagioclase crystals are much smaller than the orthoclase feldspars of the porphyries and generally of a glassy white color. A hand specimen of porphyrite might readily be mistaken for granite but its spotted appearance can generally be detected, distinguishing it from the latter. Hornblende decomposing gives these rocks an olive green color, hence their name of "green stones."

Porphyrite may be observed forming intrusive sheets in the walls of several of the canons of South Park, such as Buckskin or Mosquito canon.

Diorite constitutes some of the principal eruptive peaks of the Elk Mountain range, such as White-rock Mountain, and the rocks along Copper Creek near the Sylvanite mine. A great mass of quartz-mica-diorite much decomposed and spotted with iron pyrites overlies the ore-bearing limestone in Vallejo gulch, in Aspen Mountain, and is traceable for many miles in the direction of the Elk Mountains, from whose eruptions it was doubtless derived.

These are the principal eruptive intrusive rocks met with in our mining districts, and we pass over the "extrusive" eruptive rocks, such as the dark basalts and dolerites, the pale rhyolites and dark andesites, because they are rarely found associated in any important way with our ore deposits.

METAMORPHIC ROCKS.

There is another class of rocks, however, which the miner meets with which are generally more or less crystalline in character but are neither eruptive nor intrusive. Their crystalline character, however, shows they have been subjected to a certain amount of heat. These are called metamorphic or changed rocks, because they were originally common sandstones, shales or limestones, such as we find underlying the prairie, and have been partially changed or metamorphosed by heat into a crystalline condition very unlike their original one. To this class belong granite, gneiss, schist, syenite, quartzite, slate and marble, and we might add anthracite coal and graphite.

Granite, as we have shown earlier in this treatise, was in all probability a sedimentary rock, such as sandstone, its materials derived from the sand washed from the primitive crust of the earth. By heat, pressure, alkali, and other chemical ingredients, it has been changed into the purely crystalline rock we find it, and without being actually fused like the lavas, it seems to have been softened to such a degree that it has lost even its signs of stratification and appears massive. We find few evidences in Colorado of its being eruptive. It never occurs as a dyke penetrating the overlying limestones or sandstones or in intrusive sheets amongst them as the porphyries do.

It appears to be the bed rock of the world, underlying our prairies and the foundation of our mountains, and was, as we have said, the shore line upon which our sedimentary rocks were deposited. Gneiss is simply stratified granite; *i. e.*, granite that has not been so completely metamorphosed and softened as to entirely lose the signs of its primitive bedding and stratification. It is not structureless, therefore, and massive, like granite.

Syenite is the same as granite, only hornblende takes the place of mica. Granite is composed of mica, quartz, and feldspar. Syenite of hornblende, quartz and feldspar. Mica and hornblende schist is granite or syenite in a finely laminated condition, corresponding to mud shales in the unaltered rocks.

Structureless granite is not so common generally in Colorado as gneiss and schist. Up the Platte canon it is finely represented in Dome Rock and the Cathedral Spires. The Sawatch range is principally granite. As a rule it is commoner in the heart of the mountains than near the flanks, as might be expected, since it is the deepest buried rock in the last condition of metamorphism. Its common colors are reddish from the color of feldspar, or gray from the predominance of mica. It is much traversed by veins of all kinds, principally quartz or feldspar, or both combined. Such combinations when there is little or no mica, are called pegmatite veins and it is such veins that form the matrix of most of our ore-bearing fissure veins in granite, such as those at Boulder, Central, Georgetown, etc. Granite may be distinguished roughly from porphyry by its non-eruptive occurrence and by its lacking that peculiar spotted characteristic of the porphyries. It always underlies, never overlies any other kind of ordinary sedimentary rock in Colorado.

Quarzite is another metamorphic rock; it, too, was once a sandstone more or less pure, but of more recent age than the granite, as it is generally found lying near the Archæan granite, and belonging to some member of the Paleozoic series, such as the Silurian or Carboniferous.

Heat has changed this sandstone into a quartz-rock or quartz-stone very hard and usually pure white or gray, or stained with oxide of iron. The difference between quartz and quartzite is that the latter is a quartz-stone. A stone made of fragments and granules of the original mineral quartz, cemented together by liquefied quartz.

In Colorado it may be seen forming long belts as of white masonry or brick walls, in our high mountain districts, lying on top of the granite or in strata between the limestones. As we retreat from the granite and rise into the upper carboniferous the quartzite gradually passes into hard grits and finally into common sandstones of the Triassic or more recent formations, among which few ore deposits are found.

Quartzites may contain both gold and silver-lead deposits, more especially the former. They are hard rocks to mine in.

LIMESTONES.

Our ore bearing limestones are usually of two or three varieties and are mostly confined to the Silurian and Carboniferous or Paleozoic rocks. These are, generally speaking, in Colorado, magnesian limestones, commonly called dolomites. Some few are ordinary limestones of nearly pure carbonate of lime. They are mostly silicious, especially those of the Silurian period next to the quarzites. White nodules of chalcedonic chert or flint are very common in them, and give them a rough appearance where erosion has caused the chert to stand out on the surface. The Silurian limestones are characterized by *white* chalcedonic flints or cherts and by a general pale-yellow, light-gray or drab appearance. The carboniferous limestones above them, by a more massive structure, by the occurrence of *black* chert nodules, and by a dark blue gray color. The Silurian dolomite is locally called "white limestone," the carboniferous "blue limestone" for distinction. At a few points in the mountains these limestones have been metamorphosed into marble and serpentine.

Argentiferous lead ores are found in both these limestones, but the Carboniferous "blue limestone" has been the greatest producer. At Aspen the blue limestone is an ordinary carbonate of lime or true limestone above, passing into a dolomitic or magnesian state below. The ore occurs penetrating both forms of the limestone.

Outside of these characteristic rocks comparatively few deposits of importance have been found in Colorado. Hence prospecting has yielded little in the upper Carboniferous grits that overlie the productive limestone. An exception occurs, however, at Kokomo, where the Robinson mine has been a large producer in a belt of true limestone in the upper part of these grits. The region around Crested Butte and Irwin is also another exception, where, as we have said, fissure veins penetrate through all the formations alike.

PREJUDICE IN FAVOR OF AND AGAINST CERTAIN ROCKS.

There is often a prejudice amongst miners in favor of certain rocks and formations, and against others. Miners who have worked perhaps in the great Comstock mine of Nevada, or the Leadville mines of our own State, or the fissure veins in granite of the Old World, are apt to look out for and favor certain rocks and formations they find like those they have been accustomed to. Thus, as Mr. Williams says, "The peculiar 'porphyry' of the Comstock was hunted up in other districts, but did not prove metalliferous." "Solid granite was locked upon by others as unfavorable, generally, because locally some granite above the gold belt of California had proved barren. Yet some of our best veins are in granite."

"Limestone was at one time a very unpopular rock and supposed only locally to produce lead, till the discoveries of Leadville and Eureka, Nevada, overturned the scale in its favor."

In the Leadville "excitement" not only was the particular Carboniferous limestone of Leadville hunted for and prospected, but every other limestone in the South Park region, no matter what its geological age or position, was extensively prospected without results, miners not recognizing the fact that it was not limestone generally that produces rich ores, but a *particular* limestone of a particular geological period (the lower Carboniferous) not over 200 feet thick, that happened locally to be rich near Leadville, and the reason of its being locally rich at that point was owing to the concentration of eruptive energy at that point and the intrusion of an unusual amount of porphyries, which in point of fact are far more responsible for the ore than the limestone, which happens to be merely the receptacle.

It was also quite common after the Leadville excitement to find shafts in all sorts of improbable and hopeless localities whose owners would tell you : " At Leadville it didn't matter where a man 'went down.' It was all luck whether you 'struck it' or not, and so they might as well ' go down ' where they were as elsewhere." It was often said " that Leadville had exploded all so called scientific theories about ore being in one formation or locality more than another. It was all a case of luck."

The excuse for this is to be found in the fact that in the immediate vicinity of Leadville it did scarcely matter " where you went down," seeing that that area was practically underlaid by bedded sheets of mineral, but that such would be the case elsewhere and everywhere or anywhere, experience unfortunately has shown to be untrue. It is not a particular rock or formation, but a combination of favorable circumstances that alone can make a rich mining district.

As experience advances geologists and miners have proved that ore deposits have a much wider range than was once supposed. Formerly only the Archæan granite series was supposed capable of bearing ore deposits, because in the Old World, tin, copper and lead came principally from fissure veins in those rocks. Then deposits were found in the Paleozoic series and supposed to ascend no higher. But in the present day, and even in Colorado, they are traceable even to the Tertiary.

It is not the rock, nor the age, but a combination of circumstances, principally heat and metamorphism, that may make any rock of any period an ore-bearing one. And in prospecting in new regions it is these combinations rather than any particular rock that should be looked for.

STRIKE AND DIP OF COLORADO VEINS.

The dip of veins in Colorado approaches more nearly the vertical than the horizontal, usually from 75° to verticality. Nearly all our ore deposits, even those of the bedded class, dip more or less steeply from 25° to 75°.

For a few feet from the surface, on the steep slope of a mountain, it is common to find an ore deposit dipping quite gently or even folded over and dipping in a contrary direction to that which it assumes with depth. This appears to arise from the weight of the strata above it tending to bend it over downward in the direction of the slope of the hill.

There is generally a prevailing dip and strike amongst a number of parallel fissure veins of a district. In the San Juan, the bulk of the fissure veins have a prevailing northeasterly strike and a dip to the southeast. The angle of dip is generally between 60° and verticality.

CROSS-CUTTING UNCERTAIN.

The dip, as we have said, not unfrequently changes considerably with depth, usually becoming more and more vertical. From the degree of uncertainty as to the continuity of the dip, it is not always safe, on the discovery of an outcrop, to endeavor to cut it at a much lower point, so as to get the coveted depth, and better opportunities for stoping, drainage and other developments of the mine. Owing to a change of dip or fault, perhaps, the miner may have to make a much longer cross-cut tunnel than he had calculated upon before striking the vein. Sometimes, too, he may miss the vein altogether, cutting it perhaps at some point where it is exceedingly thin or poor, so poor in fact that he passes through it without noticing it or believing it to be the same vein whose outcrop looked so promising on the surface. Cross tunnels through "dead rock" should hardly be undertaken until the vein has been proved to be a strong one for a considerable depth. As we have already shown, great depth may not after all be so desirable in even a fissure vein, as there is no certainty whatever about veins becoming richer or poorer with depth. Extensive cross-cut tunnels have seldom proved paying concerns. The greatest in the United States, the Sutro tunnel, six miles in length, which tapped the Comstock fissure at a depth of 2,000 feet, did not prove a financial success, and had it tapped the fissure still lower, at 3,000 feet, it would have found the vein in the impoverished condition it is to-day. It is not uncommon for a miner to strike a rich outcrop on the top of some mountain, and on the strength of its richness induce a company to run a long cross-cut tunnel in " dead rock " half through the mountain to cut this vein, and the company's resources are nearly exhausted in so doing, while the vein itself gives no returns, owing to its being left idle. Finally, perhaps, the vein is missed, or if struck, proves far poorer than was anticipated. Of course there are exceptions where cross-cut tunnels in " dead rock " may be advisable.

If a fissure vein, as in the San Juan, should outcrop near the top of a mountain and be exposed on its dip all the way to the bottom, there may be some reason for opening a tunnel in it near the base, thereby facilitating drainage, development and exportation. In that case the miner is *on* the vein, with no fear of losing it; but even here, there is no guarantee that it will prove rich all the way to its outcrop a thousand feet above. "Follow your ore," is a common and wise saying among experienced miners, "and be careful how you leave it for any experimental theories." We remember a tunnel in the Gunnison region which was run several hundred feet at a cost of many thousands of dollars, all through " dead rock," in the hopes of cross-cutting a certain ore body that had proved rich near the surface. At last it was given up, and subsequently a short cross-cut was made from it, and the original vein was found only a few feet from the tunnel, which had been running parallel with it all the time. The cause of the mistake was an unforseen fault in the vein that had shifted its dip much further on one side than had been calculated upon.

STRUCTURE OF VEINS.—VEINSTONE OR GANGUE.

In most ore deposits, whether they be called fissure veins, true veins, gash veins, blanket veins, or by whatever name they may be designated, the space between the confining " country rock " or " walls " on either side is occupied by " gangue " or veinstone, consisting generally of some of the elements of the adjacent country rock in an altered or more sparry condition than in the parent rock.

The commonest of these veinstones is *quartz*, which is usually massive or of coarse or fine crystalline structure. In the San Juan region it is commonly a very fine-grained, hard, jaspery material, of a blue-gray color; in other places coarsely crystalline, like loaf sugar, and frequently contains beautiful little cavities called "vughs" or "geodes" or "drusy cavities," lined with long, perfect quartz crystals. In the San Juan these cavities are most abundant toward the center of wide mammoth veins.

Lime is a common veinstone or gangue, particularly in limestone districts. It is in a white or yellowish crystalline condition, the crystals assuming various forms, or forming a crystalline mass. Crystalline dolomite also occurs in the dolomitic limestones of Leadville and Aspen. Stalactites of arragonite, another form of calcspar, are characteristic of the cavernous openings found associated with lead ores in limestone.

At the Silver-islet Mine, Pitkin Co., in the Sacramento Mine, South Park, and in several of the Leadville and Aspen mines, such caverns lined with stalactites occur. These caverns appear to have been formed after the deposition of the ore bodies, since they are hollowed out of limestone and ore bodies alike, by surface waters, which, descending through the natural jointage planes in the limestone, have by the assistance of carbonic acid, enlarged those jointage cracks and eventuallay formed caverns, either in them or in the lines between the stratification planes.

A beautiful rose-colored carbonate of manganese called *rhodocrosite* is found in the gangue of some of the mines of San Juan and South Park. In South Park at one locality it is associated with quartz in a vein in granite.

Fluor Spar, one of our softest minerals of a pale green, sometimes of a purple color, occurs in fissure veins in the granite rock. In Bergen Park a deposit occurs of sufficient size for development for flux for the smelters. The white Cretaceous limestone of the plains has of late superseded its use.

Baryta occurs as a veinstone associated sometimes with lime crystals in the limestone districts, such as Aspen, Leadville and South Park, where those limestones have been penetrated by eruptive porphyries. While veins of calcspar, common enough throughout the limestone rocks may or may not locally indicate the presence of mineral, the presence of baryta is a pretty sure indication of a mineral lead. It is a significant fact showing the relations of ore deposits to porphyry that baryta is detected as an element in the feldspars of certain porphyries.

Baryta, though resembling calcspar, can be distinguished from it by its greater heaviness, its not effervescing with acids, its emitting a green flame and "decrepitating" or flying to pieces under the blow pipe. Its lustre is more pearly than ordinary calcite. As it usully occurs massive, its different crystallization is not always to be seen.

Baryta is not confined to limestone regions, for we find it forming the gangue in several mines in the eruptive rocks of San Juan, notably at the Bonanza Mine on the shore of Lake Como, where it is associated with a good deal of gray copper. In Hall's Valley it occurs in a vein in gneiss also associated with rich deposits of gray copper.

It is a refractory substance in smelting processes and troublesome if in excess.

With these veinstones is a good deal of oxide of iron, and sometimes oxide of manganese, together with carbonate of copper stains. Carbonate of iron in the form of spathic iron or siderite very like orthoclase feldspar in appearance only heavier, occurs in the gangue of the Whale and Freeland Mines at Idaho Springs.

The surrounding country rock generally determines the character of the gangue. Thus limestone yields carbonate of lime for veinstone, granite its elements of quartz or feldspar, or both combined in what is called "pegmatite" or granulite. The porphyries yield a clay composed of the elements of their feldspars and some quartz; they also seem responsible for the baryta.

The gangue so far from being a foreign substance derived from unknown rocks in the bowles of the earth and filling a fissure through ascending solutions, is on the contrary immediately derived from the adjacent country rock, and often consists of little more than a slight alteration or decomposition of that "country rock" along a crack, fissure, or other line of weakness. Sometimes the gangue is a porphyry dyke more or less decomposed or highly charged with pyrites lying between walls of granite or some other country rock.

DISTRIBUTION OF ORE IN THE GANGUE.

Through these "gangues" of various characters the precious metal is distributed in long narrow pacthes or strings or in large crystalline masses, or in insolated or scattered crystals, or in decomposed masses.

The gangue matter is generally in the majority and the ore thinly, sparingly and irregularly distributed in it. When a vein is said to be ten feet wide it is not to be supposed that ten solid feet of mineral from wall to wall is meant, but that that is the width of the gangue, while the ore body may occupy but a few inches of that width, or be sparsely scattered over it, the remainder being quartz or some other veinstone.

It is common to find one or more rather definite and continuous streaks or courses of ore having a tendency to keep near one or the other wall, or at times to cross from wall to wall. This is called the "pay streak," and is the main source of profit in the mine.

HIGH AND LOW GRADE ORES.

In gold veins, flakes or wires of free or native gold occur in the decomposed gangue, and sometimes in the pure undecomposed quartz. Native silver is found in the same way, but more as cabinet specimens than in any continuous body. Isolated patches of very rare or valuable minerals, such as ruby-silver, horn-silver or silver-glance, occur locally in parts of the vein, or sometimes line the stalactites or crystals of some "vugh" or drusy cavity. An assay of such picked specimens would, of course, give a very unfair average of the mine. As a rule, the bulk of the profits of a mine are derived from the common minerals, such as galena or pyrites, and the secondary products of these, such as carbonate of lead or iron oxide. It is from the ores, too, of comparatively low grade that the steady annual profits of a mine are derived. In California gold mines the average yield of gold per ton was $16. In Dakota, $6. In the silver mines of Leadville the average to the ton is rarely more than $40, and the bulk of the ores of that richest of camps is generally of low grade. There are a few mines of extraordinary high grade in sufficient quantities to yield from $75 to $100 per ton, such as some of the mines of Aspen, but these are exceptions rather than rules, and even these have a large quantity of low grade ore on hand. Quantity of ore and facilities for milling, and the size of the vein and its facility for work, or its nearness to market, give the offset.

DECOMPOSED ORES.

Sometimes the gangue matter contains a variety of decomposed ores in rich secondary combinations intimately mixed through its mass, and rarely discernable by the naked eye. Thus a mass of seemingly yellow mud may be found by assay to run high in silver from the concealed presence of chlorides or sulphurets of silver in it. No accurate estimate of the value of a mine or even of a piece of ore can be formed without an assay or a mill run being made. A vein may appear sparkling with masses of galena or glittering with golden pyrites, and seem to the unexperienced a perfect bonanza of wealth. The assay or mill run value may show the galena to be very poor in silver or the pyrites to yield no gold. On the other hand a mass of heavy rusty dirt may assay up into the thousands. The reason for such richness in decomposed surface products appears to be that nature has been for ages leaching out, concentrating and combining in richer forms the essence, so to speak, of the vein. A rich mine in the San Juan ships nothing but yellow mud, and another, the National Belle, at Red Mountain, yielded similar materal when we visited it, which had to be dried before shipping, but gave steady and good returns. It is evident then, how unsafe it is to judge of a mine by the sight alone. Truly "all is not gold that glitters," and the necessity of a thorough assay or mill-run when possible, of portions of every accessible part of the vein, and especially of those poorer portions which yield the daily average, is obvious before the real value of a mine can be estimated.

GRAY COPPER.

Besides the ordinary galena and pyrites we often find considerable bodies of *gray copper* intermingled with other ores. This is nearly always a rich ore, varying, however, in different localities from 60 oz. silver to several thousands per ton. It occurs generally in the massive state, rarely showing its pyramidal "tetrahedrite" crystals.

In appearance it is not unlike a freshly broken piece of bronze, tin or iron. It is more common in the fissure veins in the granite and eruptive rocks than in limestone deposits. In Hall's Valley it is associated with baryta in a vein in the gneiss. It occurs in the Georgetown veins in granite. In the San Juan district it occurs also associated with baryta in the Bonanza mine, and an ore not identical with it in composition, but very like it in appearance, called bismuthinite, consisting of bismuth, antimony, copper and silver, is characteristic of that region and is rich in silver. Bismuthinite has a more shiny tin-lke appearance than gray copper, and the red color which bismuth gives to charcoal under the blow-pipe readily distinguishes it from gray copper.

LOCAL VARIATIONS IN VALUE OF ORES.

There are locally in different mining districts considerable differences in the value of certain minerals and ores. In one district gray copper may rarely exceed 60 ounces of silver, in another it is invariably over 100 ounces.

A coarse galena is generally poor in silver, while fine grained "steel galena" is generally rich in silver, but the reverse may also be the case. In some of the mines at Aspen fine grained galena, especially near the surface, is quite poor in silver, while in other mines in the same district it is exceedingly rich. Localities occur also where coarse grained galena runs well in silver and is richer than fine-grained galena. This is the case at the Colonel Sellers mine at Leadville. So one mining district or even one mine is not a rule for another.

PYRITES.

Iron pyrites and copper pyrites, common in most of our quartz veins in granite and in the eruptive rocks, may yield both gold and silver, but usually the former. There are certain districts more characterized by pyrites than others, such as the Central City district. These are generally gold-producing districts. Some of the mines of Breckenridge and South Park have strong pyritiferous veins in eruptive dykes, such as the Jumbo mine. These have of late produced a great deal of gold. The same district, however, produces large argentiferous lead veins. Pyrites generally favor the granite, eruptive and crystallized rocks. The quartzite of the lower Silurian of South Park and Redcliff are often pyritiferous and generally gold-bearing. In limestone the pyrites is rare or absent, its place being filled by some form of iron oxide. In the deeper mines of Leadville, however, this iron oxide is beginning to pass down into the iron sulphide or pyrite from which it was derived. Iron pyrites can generally be distinguished from copper pyrites by its paler, more brassy color, by its superior hardness and by its crystallizing in cubes. Copper pyrites much yellower and softer, and crystallizes in a more pyramidal form. A vein may glitter with showy pyrites and yet be quite valueless. It usually yields more gold in its decomposed, oxidized condition than in its unaltered state. In the one case the gold is free-milling, and in the other it must be smelted at much greater expense.

"SULPHURETS."

This term amongst miners is loosely used, and often means some decomposed ore whose ingredients cannot be determined at sight, but which somehow assays high in silver. True sulphuret or sulphide of silver is a name embracing a large family of rich silver ores, among which are stephanite or brittle silver, argentite or silver glance, sylvanite or graphic tellurium, and polybasite.

All these rich ores are compounds of sulphur and silver and other ingredients in varying proportions. They are somewhat alike in appearance and not always so easy to distinguish.

Argentite, silver glance, or sulphuret of silver, is of a blackish, lead-gray color, easily cut with a knife, and consists of an aggregate of minute crystals. Its composition in 100 parts is sulphur 12.9, silver 87.1. Under the blow-pipe it gives off an odor of sulphur, and yields a globule of silver.

Stephanite, or "brittle" or "black" silver, is closely allied to argentite. Its composition is sulphur, antimony and silver, silver being 68.5 per cent. The crystals are small. Under the blowpipe it gives off garlic fumes of antimony. Yields a dark globule from which, by adding soda, we get pure silver.

Polybasite, common at Georgetown and in some of the Aspen mines, such as the Regent or J. C. Johnson, on Smuggler Hill, is like the others, but of a more flaky, scaly and graphitic appearance. It is not unlike very fine-grained galena, yielding 150 to 400 ounces of silver per ton.

These sulphurets sometimes line little cavities in limestones with a dark sooty substance which under the microscope prove to be crystals of one of the sulphurets of silver. Sometimes also a rock is stained all through a blackish gray by these sulphurets. Iron or manganese may produce much the same effect, but an assay will soon reveal the difference. Associated with such a rock we may see flakes or wires of native silver that have emerged from the sulphide state.

CHLORIDES.

Chloride of silver, "horn silver" or cerargyrite. This is another result of secondary decomposition from a sulphide state, (silver sulphide.) It is a greenish or yellowish mineral, like wax and easily cut with a knife, it is a very rich ore running 75.3 per cent. silver, the remainder being chlorine. As a secondary product of composition it is generally found near the surface or in cavities, sometimes deposited on calcite or other crystals. In the mines of Leadville it is commonly associated with other decomposed ores such as carbonates. In the Chrysolite mine, a mass weighing several hundred pounds was found. Chloride, bromide and iodide of silver are closely related, being compounds of chlorine, bromine, iodine, and silver. It is noticeable that these salts are the elements of sea water, and that these ores are often found in marine limestones. According to Mr. Emmons the change at Leadville from sulphide to chloride was produced by surface waters; these waters are found to contain chlorine, which they probably derived from passing through the dolomitic limestones which contain chlorine in their crystals and these limestones perhaps originally derived it from the sea water in which they were deposited. Chloride of silver is found at Aspen and abundantly in the out-crop of mines in New and Old Mexico.

SULPHARSENITES.

Ruby silver, (pyrargyrite and proustite.) Composed of sulphur 17.7, antimony 22.5, silver 59.8=100. Crystallizes in rhombohedrons is seen in spots or crystals on a mass of ore of a deep red or blackish tint. When scratched with a knife it shows a bright or deep red color. In some mines this very rich ore occurs only as specimens, but in others it is present in sufficient quantity to largely influence the value of the ore in bulk. In parts of the Granite Mountain Mine in Montana it constitutes the principal ore, associated, however, with other mineral. It there occurs in large masses and accounts for the extraordinary richness of that celebrated mine. Proustite is much the same only lighter red and consists of sulphur 19.4, arsenic 15.1, silver 65.5=100.

CARBONATES.

This term also embraces a large family, the commonest being carbonate of lead, (cerussite) and carbonate of copper, (malachite and azurite.)

Copper carbonate can never be mistaken owing to its brilliant green and azure blue color. Copper stains are among the common surface signs of a "lead." It is generally associated also with rusty stains. Both are the surface products from copper and iron pyrites forming a vein below ground which may or may not be profitable. Copper stains are common enough in many rocks, but do not always lead to bodies of ore. In South Park the red Triassic sandstones are so stained, but yield no ore. Along our foothills there is quite a stained belt from Golden to Morrison and through Bergen Park. But few promising deposits of copper or other ores have been found, although handsome specimens of native copper have been discovered near Golden.

At the Malachite mine on Bear Creek, near Morrison, a prospect was at one time opened showing a good deal of silicate of copper (chrysocolla), and malachite, but for some reason it has not been worked since.

Copper in its native or uncombined state is rare in this State, and so far we have as yet no true profitable mine. A great deal of copper is found associated with other ores, and is extracted by some of the smelters. Carbonate of copper is commonest in the limestone districts as might be expected from the carbonating influence of limestone upon minerals in it, or mineral solutions passing through it. Carbonate of iron (spathic iron, or siderite), constitutes part of the gangue matter in some of our veins, and may also be found associated with coal seams generally, in the latter case in an oxidized condition.

Carbonate of lead (cerussite). This is mostly found in the limestone districts, such as Leadville. It is there known in two forms, one called "hard carbonates," the other "soft" or "sand carbonates." The crystals of this ore are small prisms, sometimes combined into a cross shape, of a pale grayish white, and might be taken for some form of carbonate of lime or gypsum, their weight, however, soon shows the difference. They are a secondary product of decomposition consisting of carbon dioxide and lead oxide, as a carbonate they effervesce in nitric acid, and yield lead when heated. Cerussite is exceedingly rich in lead, carrying 75 per cent. The white lead of commerce has the same composition. In Leadville and elsewhere in Colorado it is silver-bearing also, and though low in silver, the facility of its treatment at the smelter makes it a very desirable ore. As a rule it contains less silver than the unaltered galena, but is more easily treated than the latter. The process of change or derivation from a sulphide state (*i. e.*, from galena) to a carbonate, is well shown sometimes in a piece of Leadville ore. A central cube of galena is surrounded by a grayish green ring of sulphide of lead or anglesite, and outside this may again occur crystals of lead carbonate. Thus the process is from a sulphide to a sulphate, then to a carbonate. The so called "hard carbonates" is a brown mass consisting of a hard flinty combination of iron oxide and silica, impregnated with crystals of lead carbonate, with which are often silver chlorides, also. The "sand carbonates" result from the decomposition and breaking up of the hard carbonates, or from a mass of pure crystals of carbonate of lead, which are, by nature, loose and incoherent. The Leadville mines are getting below these products of decomposition and entering upon the original sulphides of galena and iron. The yield, however, is said to be equally good.

ZINC-BLENDE (SPHALERITE), "BLACK JACK."

Common in most mines mixed with other ores. As it is a very refractory mineral in smelting, much of it is not desirable in a mine.

It is easily recognized by its brown resinous look or when very black by its pearly lustre. At Georgetown, near the surface, brown "rozin zinc-blende" carries silver, and is associated with rich ores, such as polybasite and gray copper. With depth the zinc-blende becomes more abundant and blacker, and loses much of its silver properties. Zinc-blende may run from nothing to twenty dollars silver, and rarely as high as $100 per ton.

In some mines in the San Juan it occurs abundantly near the surface and fades out with depth. We have no true zinc mines in this State, the zinc being mixed with other ores. In some mines in Pitkin County the zinc predominates over all other ores, and though it runs high in silver the smelters do not care to take it, on account of its refractory character. In the Eastern States where zinc smelting is a specialty such ore might be separated and both silver and zinc saved.

In Colorado there are no mines of one mineral alone, as in some other parts of the world. We have no true lead, zinc or copper mines; these baser metals are either argentiferous or auriferous, and their baser qualities are sacrificed for their richer ones.

"BRECCIAS" AND "HORSES."

Some lodes enclose fragments of the country rock. When these are small and angular the vein is said to be "brecciated;" when they are large so as to split the vein they are called by miners "horses."

Breccia usually occurs in large veins near the walls. This is frequently seen in the fissure veins of the San Juan region. Fragments of the adjacent eruptive rock are enclosed by a bluish quartz.

In the same region, where we have extraordinary opportunities of seeing complete sections of great fissure veins descending the face of a cliff for 2,000 feet, on either side of a profound cañon, a broad vein is at intervals observed to split up into two or three arms enclosing large fragments of the "country rock," and these are then seen to unite again in a broad vein, which at another interval will again include a large "horse," or split up into a number of branches, which again unite to form the main vein.

These veins occupy a once shattered fissure, the walls of which are neither straight nor regular, but shattered either into small fragments near the vein, or into large ones extending into the country rock. The vein material has insinuated itself in between the shattered portions, sometimes enclosing small fragments and producing a "breccia;" at others around large fragments, producing a "horse." Sometimes the brecciated fragments are surrounded by rings of ore, and are called "cockade ores."

SUBSTITUTION BY SILICA.

Quartz substitutes itself for mineral elements or portions of the country rock, as matter in a wounded limb substitutes itself in the place of the natural flesh. Rocks have been wounded by narrow cracks; these cracks have been healed by silicious matter oozing or supplied from the adjacent rocks in solutions; the solution matter not only heals the crack, but eats into and substitutes portions of the country rock on either side the original fissure with its own matter; and so, we think, are sometimes formed wide fissure veins of quartz, the original crack or fissure being perhaps not an inch in width, but simply a line of weakness for mineral solutions to work upon and exercise substitution. This substitution or metasomatic replacement is not unlike that which takes place in the fossilization of a tree-trunk. A tree falls into a marsh, is buried in mud and sealed from contact with the air. It is soaked with water carrying silica in solution; as the cells of woody fibre gradually rot and pass away each molecule of wood is replaced by a microscopic molecule of silica. The result is a tree substituted or replaced by silica, or as we say, a silicified, fossilized trunk. So breccias may be sometimes formed by quartz substituting itself for portions of the country rock, leaving harder or unchanged portions not yet substituted still remaining in the vein surrounded by the quartz. Fragments forming breccias do not seem to have fallen into a wide, gaping fissure, gradually filling up with quartz in solution, and so got entangled in the quartz, for many of the pieces will match one another, and appear rather as if quartz in solution had enlarged slight cracks between the fragments, or else, as we have said, substituted a large portion of the country rock, leaving portions still unsubstituted. "Enclosed fragments of country rock are nearly replaced by silica, leaving only a shadowy image of their original forms."

"BANDED, COMBED OR RIBBON" STRUCTURE.

"The various minerals filling a vein fissure are frequently arranged in a succession of bands parallel to the walls. These

bands or 'combs' are aggregations of crystalline minerals, the separate crystals of which are usually arranged with their longer axes at right angles to the walls of the lode, while their crystalline form is more perfectly developed at the ends turned towards its center than at the other extremity." These combs meeting, if their crystals happen to be long pyramids of quartz, remind one of two rows of teeth clenching and interlocking.

"This 'ribbon' or banded structure indicates long-continued chemical action, occasionally interrupted, but again renewed under different conditions, the substances deposited in 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 show this comby structure, while others show no trace of any particular arrangement." Perhaps the latter case might be due to greater pinching or pressure, not admitting of freedom for crystallization. Toward the center of large quartz veins, "vughs," or cavities of a lenticular shape occur, lined with beautiful quartz crystals, their points pointing to the center of the cavity, at right angles to the wall There seems to have been an open space here, or a relief of pressure sufficient to allow the quartz to crystallize out in such large and perfect forms. If the vein was filled by "lateral secretion," *i. e.*, by solutions coming from the sides and forming on either wall, there would be naturally a space in the middle. In the basaltic rocks of Table Mountain, at Golden City, cavities have been formed in the molten lava by steam bubbles. These cavities were subsequently lined by a succession of zeolite crystals, first chabasite, on this thompsonite, and lastly analcite. The minerals for these crystals were derived by solutions from the basalt in different degrees of combination, and so crystallizing in different forms. This is probably analogous to the vein ribbon structure. "Fortification" and ribbon agates are of the same nature.

Vein fissures, being a line of weakness, have occasionally been re-opened and a new or different character of veinstone or mineral formed in the interstice, giving rise to a series of alternate "ribbons."

The re-opening of a fissure has been attended by a grinding together of the walls, resulting in slickensides and gouge, and this may account for the appearance of gouge in the center or heart of a vein which has been re-opened.

The arrangement of the minerals in these alternate bands or ribbons could only be produced by solution or sublimation. The successive layers are produced by deposits parallel to the walls, while the crystals have their axes directed to the center of the vein. This banded, ribbon, combed and "vugh" structure is common in the San Juan district.

"In vein fissures," says Phillips, "formed at different periods, the mineral deposits 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, hence the variety of minerals found at intervals in a mine. In nearly all wet mines secondary minerals of various kinds are in progress of formation from the original sulphides of the vein proper." Galena that has been left lying on a dump for many years has been known to pass gradually into a sulphate and thence into a carbonate of lead.

CHANGE OF MINERALS WITH DEPTH.

Lodes often change in the character of their minerals with depth, not only after they have left the zone of secondary decomposition and surface action, but also far below it. Thus, in the San Juan some of the mines abound in zinc-blende near the surface, which with depth almost disappears, giving place to gray copper and other superior ores. In Cornwall, England, the shallow workings yield copper, and with depth, tin; and locally, many such changes may characterize a particular district, but cannot be formulated as a rule for other localities.

INFLUENCE OF COUNTRY ROCK.

In most mining regions, to which Colorado is no exception, a relation has been observed between varieties of "country rock" and ore deposits. Veins in passing from one country rock to another are liable to change in the size or variety of the ore, widening in connection with some rocks, and pinching or growing narrower in connection with others.

Certain rocks are notorious ore-bearers, whilst others are notoriously barren over large regions, or in special localities.

The presence of certain rocks adjacent to other different rocks has an enriching tendency on the ore bodies.

As regards rocks that are good ore-carriers or receptacles of particular classes of ore in Colorado, we may say that quartzites and silicious rocks generally carry more pyrites, and are gold-bearing.

That veins in granitic rocks carry a greater variety of minerals than others, and may be both gold and silver-bearing.

That certain limestones carry much argentiferous galena.

That sandstones and other unaltered rocks carry little ore of any kind.

The influence of country rock on veins may be from several different causes, for instance:

Certain rocks are by their structure better adapted than others for forming regular fissures. Thus, massive limestone is better fissured than slate or shale, leaving wider open spaces for the ore to collect in.

Other rocks may be more porous, and admit mineral solutions through their pores. Of such a kind are some of our porphyries.

Others, like limestone, are easily acted upon by solutions dissolving out the rock and replacing it with mineral by substitution.

Some are better conductors of heat, and therefore would assist chemical action and mineral solution.

And lastly, if modern theories of "lateral secretion" be true, viz., that most ore comes from the adjacent country rock and is precipitated, substituted, or collected in the vein fissure, and further, that the metals themselves are derived from certain metallic elements in the ordinary constituent minerals of the country rock, such as mica, hornblende, or augite, it is clear that a rock composed largely of such minerals would be liable to influence the vein as an ore generator. Granite and porphyries are largely composed of these minerals.

The frequent presence of eruptive porphyry rocks near veins and ore deposits in Colorado shows that they have an important influence on those deposits, which may be of various kinds.

First, that in their component minerals and mass they actually contain the elements of the precious metals subsequently deposited in another form in the fissure vein or in the soluble limestone in contact with it.

Secondly, by the heat which they retain for a long time after they have congealed and hardened, they would assist in the reactions of any chemical or mineral solutions that might be on hand. Lava, at the time of its eruption, is always highly charged with steam and other gases. By reason, also, of the chemical composition of porphyry, waters passing through it would be alkaline and assist in dissolving silica and other gangue or veinstone matter, and when the porphyry has thoroughly cooled it is exceedingly porous, and being much jointed and cross-fractured, becomes like a great sponge for the absorption of all surface waters. This may be noticed at Aspen, where all the mines that are at present penetrating through the "porphyry cap" are much troubled with water, far more so than in the underlying limestone. Surface waters, then, becoming alkaline by passing through this rock, and also more or less charged with carbonic acid, chlorine, and other solvents, would be ready to dissolve both gangue and vein ingredients out of the porphyry and redeposit them in the vein fissure, or, by metasomatic substitution, in the limestone usually beneath it.

Water circulating in fissures changes or dissolves the ingredients of the surrounding rock. The rocks enclosing lodes are always so altered, and this decomposition and alteration is not always merely local or confined to the close proximity of the ore body, but we often find a whole mining district, such as Leadville, Aspen and San Juan, pervaded by this feature. So much is this the case that it is often difficult to get a fresh, unaltered specimen of porphyry or some other country rock within the district.

The brilliant red, yellow and maroon tints that color so much of the mining district of San Juan result from the oxidation of pyrites and other iron-bearing minerals pervading the eruptive rocks, and it is noticeable that this color, resulting from alteration and decomposition, is most prominent in those parts where lodes have been discovered, as, for example, the gorgeous tints of the Red Mountain area around the celebrated "National Belle," "Yankee Girl," and Ironton mines, between Silverton and Ouray.

The rocks in Geneva Gulch, Hall's Valley, Buckskin Cañon, and in other mining centers, display the same beautiful tints of oxidation in the vicinity of the mines.

"In lodes a mutual exchange takes place through the reaction of the ingredients of the rock and the materials of the vein. Thus, when water containing carbonates comes in contact with rocks or minerals containing alkalies, a chemical reaction takes place. When these last are combined with silicic acid, these silicates are decomposed by the carbonic acid and the bicarbonates. This explains both the crystallizing out of the carbonates and the so frequent decomposition of rocks containing lodes, especially those which, like our veins of granite, are feldspathic."

The same principle applies to other ores and minerals in lodes. Thus the precious metals in the mines of Leadville in their original condition have been proved by depth to have been in a sulphide state, such as iron pyrites (sulphide of iron), or galena (sulphide of lead), etc. Surface waters charged with carbonic and other acids, passing through the overlying porous alkaline porphyry and entering the underlying limestones, have, as we have previously observed, changed the sulphides into sulphates, oxides and carbonates.

The presence of a dyke near to or cutting a vein has been found often to enrich the latter at the point of contact.

In the "Colorado Central" mine at Georgetown a narrow dyke of brown obsidian traverses a larger dyke of ore-bearing porphyry. The valuable ore is found close to the obsidian dyke. This might be the result of greater heat at that point. The "black dyke" in the Comstock mine is a somewhat similar case.

PALEONTOLOGY OF ORE DEPOSITS.

By finding certain characteristic fossils in the country rock enclosing the ore bodies, we determine its geological age. Thus in Colorado, in the Leadville region, we find occasionally in the ore-bearing "blue limestone" a sort of pectinated cockle-shell with a broad groove down the middle of the shell; this is called a Spirifer (Spirifer Rocky-Montana). Another rather hump-backed, round-shouldered shell, the size of a walnut, with short spines sticking out from it, is called a Productus; and a third, of a spiral shape, not unlike a large snail shell, is called Euomphalus, and another Pleuroto-Maria. These shells being characteristic of and peculiar to the Lower Carboniferous in various parts of the world, label the geological horizon whose rocks carry the ore at Leadville as belonging to that period.

At Aspen, some seventy-five miles distant, the same fossils occur in a "blue limestone," together with a great number of fossil corals, some cup-shaped, and others full of pores like the section of a sugar-cane. The former belong to the " Zaphrentis " class of corals ; the latter are called " Syringopora."

The similarity between the fossils in the ore-bearing blue limestone at Leadville and Aspen enables us to state that the ore deposits of both regions are in the same geological horizon and the ore bodies situated in very nearly the same belt and much the same circumstances.

The importance of this is obvious. Leadville having produced so wonderfully in the past, if it can be proved that the new camp of Aspen has deposits in the same belt and similarly situated it would be so much in Aspen's favor.

Too much reliance as to the future of any camp must not be grounded on these geological facts. Local circumstances, besides those of merely being on the same geological horizon, may have much to do with the distribution of ore. Thus, while it would be wise to follow up this particular limestone, and prospect it wherever it appears between Leadville and Aspen, it by no means follows that it will everywhere prove productive of mineral. The most likely places for mineral deposit would be where it happens locally to be traversed by eruptive porphyries, or where there are signs of porphyries or eruptive rocks being in the vicinity of the limestone.

As limestones of different ages are often very similar to one another in color and composition, the finding of these peculiar fossils is very useful in tracing them over the country ; but in Colorado these fossils are not so common as we might wish, and in lack of them a prospector might form a shrewd but not very certain guess at the identity of this ore-bearing limestone by its position on a cliff section relative to other formations.

Generally speaking, this Lower Carboniferous limestone may be found four hundred to five hundred feet above the granite, the interval being occupied by a well-defined belt of white quartzite about 200 feet thick, and upon that a drab-yellow dolomitic limestone ("white limestone"*), also about 200 feet in thickness. Of course this thickness may vary much with localities. Then again, above the blue limestone usually comes a bed of black carbonaceous shales, then a thick bed of grits and sandstones, and then red sandstones. The blue limestone will lie then somewhere between the red sandstones and the granite. The long section accompanying this report will show the general position of these strata.

A lack of ability to distinguish the age and position of certain limestones has lead to a great deal of useless prospecting in Colorado. On the other hand, largely by means of these fossil shells, the Geological Survey has been able to follow the Leadville ore-bearing belt for many miles along the Mosquito range and over the range to the region around Mt. Lincoln, Breckenridge and South Park, and again further North up the Arkansas river to the Eagle river, to Redcliff, and thence to Aspen. Similar rocks, too, have been identified by means of their fossils, as far down as Tombstone, in Arizona, and Silver City, New Mexico.

To resume our section: Next below the blue limestone, with sometimes an intervening bed of white quartzite, called the "parting quartzite," comes a bed of 200 feet or more of drab-yellowish dolomitic limestone, full of white flints; it is locally called "white limestone." In this a few shells have been found sufficient to identify it as belonging to the Silurian. This limestone yields ore, but not generally so well as the "blue lime."

Below this is a bed of hard, white, crystalline quartzite, which has yielded very few obscure fossil impressions. The fossils appear to have been obliterated by the heat attending metamorphism. From its general position on top of and immediately upon the Archæan granite, and its position underneath the fossil-defined Silurian and Carboniferous above, it is considered to belong to the lowest division of the Silurian, called the Cambrian. This Cambrian quartzite has yielded gold in South Park and at Redcliff.

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*Known also as "short lime" by Aspen miners.

This brings us to the granite, in which there are no foss but it is not difficult to recognize it. It is the "bed rock" of world, the Archæan or beginning, and here paleontology stops

If we now begin again from the top of the Carbonifer limestone and ascend, we shall find dark shales, stained w coaly material, and even some small seams of anthracite coal, a among them (near Sheep Mountain, in South Park), act impressions of the singular foliage of the Carboniferous epo such as gigantic horsetail rushes (equiseta), and tree-ferns si ilar to those found overlying the coal in Pennsylvania..

These fossils confirm our opinion as to the ore-bearing lin stone being Lower Carboniferous, and that these grits and sha represent the Middle Carboniferous. The grits have not, so f produced much ore. Above this thick bed of grits, called *We grits* because they are developed on an enormous scale in t Weber cañon in Utah, we find a few beds of limestone, so shales and some coarse, dark-brownish red conglomerates.

The limestone has yielded some fossil shells, showing it to Upper Carboniferous, and at Kokomo, in Ten-Mile district, at t Robinson mine, large bodies of ore have been discovered ass ciated with eruptive porphyries. This is, with the exception the ore deposit in the Gunnison district, about the highest horiz in which ore bodies are found in place in Colorado.

[In the shales near Fairplay, South Park, the writer disco ered some interesting remains of fossil insects and foliage, whi have been determined as belonging to the Upper Carboniferou

Next follows a great thickness (from a thousand to two thou and feet) of coarse red conglomerate sandstones, supposed from their position relative to well determined Carboniferous beds below, and Jurassic beds above, to be the Triassic and to mark the beginning of the Mesozoic era in Colorado. No fossils have been found, however, to make this certain. A few copper stains is all the mineral found in this formation in this State.

Next above this are a series of variegated clays and shales, red, purple, green and gray, also a bed of thick white sandstone near the base which has been used for glass. Being nearly pure silica. There is a bed of limestone in the middle which is burnt for lime among the foothills. In the shales and clays of the upper

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ɪrtion of this Jurassic formation the writer discovered some large eletons of dinosaurs or "terrible land lizards" at Morrison on the othills and also in Wyoming. These remarkable fossils show e formation to belong to the Jurassic. Some shells discovered the limestone in Wyoming also prove the same thing. There e no important minerals in this group. Oil has been found in e saurian beds in Oil Creek, near Cañon City. Above this, ong the foothills and in the basin of the parks, is the prominent ndstone "hogback" of the Dakota group, the floor of the Cre-ceous epoch, identified by peculiar leaf fossils found in it. In e center of this "hogback" is found a bed of fire-clay of excel-it quality.

The middle or Colorado group of the Cretaceous consists of rk and drab clays full of marine shells, some of them called nmonites are often mistaken for fossil snakes coiled up. An-ıer shell, often covered with mother of pearl resembles an eel in two, and is often supposed to be a fossil fish. In the mid-e of this Colorado group, between one and two thousand feet ow the coal beds, oil has been found in a loose sandstone at orence, near Cañon City. There appears to be two horizons two oil sands near Cañon City, one in the upper Jurassic, the ıer in the Colorado group of the Cretaceous, both may probably ginate from strata of a still lower geological horizon.

Near the base of this Colorado group is a prominent bed of ite limestone, much quarried for flux for the smelters, being a arly pure carbonate of lime. In it are found large round shells out the size of a saucer, and not unlike a modern clam; these called "inoceramus." This limestone near Schofield, on Rock eek in the Gunnison, is traversed by argentiferous galena veins.

Next come the Laramie Cretaceous coal beds consisting of ndstones, clays and shales. The important coal seams lie in a ck bed of sandstones near the base of this group. Beds of erior limonite iron ore are also found a short distance above coal. The upper portions of this group for 1,000 feet have lded, at intervals, very good artesian water, at Denver and else-ere. Throughout the Laramie group abundant fossil remains tropical foliage, such as palm leaves, fig leaves, cinnamon, etc., ve been found to identify its horizon. The sandstones near the coal are quarried for building stone. The Tertiary which lies on the top of this, and unconformably with it, consists of pudding-stone, conglomerates, shales, thin seams of coal and plant remains. Its unconformity to the Laramie is among the leading characteristics that prove its Tertiary origin. It generally forms table lands, and is often capped by some form of more recent lava, the latter is quarried for building stone. Spread over all these formations alike, in mountain cañons and along river courses, we find the glacial moraines, cobble stones, sands and boulders, sometimes modified by water into stratified beds. These, as we have said, are our gold placer beds. Remains of the mammoth and mastodon have been found in these beds in Colorado, a sufficient evidence of their Glacial and Quaternary origin.

On top of this is the soil of the present age, in which we find bones of buffaloes and deer, and relics of civilized man and uncivilized Indians.

It will appear from the colored section to what a limited portion of this ten to twenty thousand feet of strata our precious metals are restricited, viz.: To the first few hundred feet of the lower and geologically older portion.

GEOLOGICAL AGE OF VEINS AND ORE DEPOSITS.

As veins are necessarily of more recent date than the rocks which contain them, we may, in a negative way, get approximately at their geological age of formation. For instance, if a series of veins penetrate the Archæan, they must have been formed during or after the Archæan. If penetrating the Carboniferous, as at Leadville, after the Carboniferous, and so forth.

But, though we can state with certainty that certain veins and ore deposits were formed *after* such and such an age, it is difficult to limit them to the exact interval of time in which they were formed. If, for example, we found a series of veins penetrating to the top of the Archæan granite and ending abruptly at the Silurian, we might suppose that they were formed after the Archæan and before the deposition of the Silurian, but the evidence would be only negative, as there is nothing to show but that they may have been formed quite recently, and that the fissures only extended to the top of the Archæan without having force enough to break through into the Silurian. For instance, at Steamboat Springs, Nevada, veins are to-day being formed by hot waters coming up through a fissure in the granite.

The ore deposits characteristic of Leadville are found in neighboring districts to extend as high as the base of the Triassic, or beginning of the Mesozoic era; therefore they must have been formed as late as the opening of the Mesozoic. We have proofs, however, that they were formed before the great upheaval movement at the close of the Cretaceous, because the deposits are folded and faulted by that movement.

Vein and ore deposits have been forming from a very early age up to the present time, and are still forming, as shown by the case of the Steamboat Springs we have alluded to.

These springs are situated on a line of fissures extending in the direction of the celebrated Comstock mine fissure. The springs emit steam from a series of parallel fissures, which are lined with successive coats of silica, assuming the banded structure observed in the veinstone of ordinary fissure veins. The fissure at one point has been opened beneath by a tunnel, and found to contain a quartz vein containing copper and iron pyrites, together with cinnabar and gold. Here we seem to have all the conditions of a fissure vein forming before our eyes.

The great Comstock mine fissure appears to have had much the same origin, and the extraordinary heat that is met with at a depth of 3,000 feet is probably the approach to the retreating and dying geyser. It is possible that some of the fissure veins in the San Juan region may have been formed by the action of now extinct hot springs and geysers, as the whole region shows evidence of great volcanic activity in past time.

ORIGIN OF ORE DEPOSITS.

From the numerous theories that have been put forward to account for the origin of veins and ore deposits, we select such as seem to us most in accordance with the facts of this difficult problem.

ERUPTIVE LODES.

Metalliferous matter is sometimes disseminated through igneous eruptive rocks, as, for example, through the gold-bearing dykes of porphyry at Breckenridge.

Metals occur in such rocks in minute particles, or as quantities of various compounds of the heavy metal. In some cases these have been chemically dissolved out, and the metals again thrown down in such a way as to form valuable metalliferous deposits. In Australia, in South Park (Colorado), near Prescott (Arizona), and in various other places, such impregnated dykes have become decomposed. The originally disseminated gold has been deposited with quartz and other minerals, in the joints and fissures of the rock. In a certain sense these may be called eruptive lodes, and owe their origin indirectly to eruptive igneous agencies.

SUBLIMATION THEORY.

Vein fissures are supposed by this theory to be filled by the volatilization of metalliferous minerals derived from the ignited interior of the globe or from intense heat. This accounts for the unequal distribution of the ores in lodes by currents of dissimilar gases or vapors circulating through fissures in the veinstone. These dissimilar vapors meeting, combine and precipitate various metals. Magnetite and specular iron are thus produced by decomposition of chlorides of iron, by watery vapors in fissures of modern volcanic rocks. Magnetite and galena have also so been formed by sublimation in the flues of smelting furnaces, and also tin oxide, zinc-blende, pyrites and other vein minerals.

This theory, though it may contain some truth, does not account for earthy minerals forming veinstone in veins, nor various other phenomena connected with veins.

Cinnabar, iron pyrites and gold are now, as we have said, being deposited from the waters of the geysers in Nevada. Quartz with its large crystals appears to be deposited by water only.

LATERAL-SECRETION THEORY.

This is one of the most important theories of modern days, and is principally due to the labors of Prof. Sandberger. "Water percolating through the country rock has by aid of carbonic acid and other solvents dissolved out of it all the materials now forming the constituents of veins."

Some lodes in this connection show a marked difference as they pass from one variety of "country rock" to another. Sandberger's examination has proved this to be due to metals being derived from those rocks, and further that the metals were derived more particularly from certain constituent minerals of those rocks, such as mica, hornblende, augite and feldspar, the common constituents of such rocks as granite, the porphyries, and other eruptive crystalline rocks.

In each of these common minerals the elements of the metals occurring in metalliferous veins were detected and proof found that the heavy metals exist in the silicates of crystalline rocks of every geological age.

In olivine, (a common crystal of basalt,) iron, nickel, cobalt and copper were found.

In augite another constituent crystal of the same and other igneous rocks, lead, tin and zinc were found.

Hornblende, common in granites and eruptive rocks, contains copper, arsenic, cobalt, lead, nickel, antimony, tin, zinc and bismuth.

White micas yield tin, arsenic, copper and bismuth.

Black micas are not so productive, but yield similar metals.

The feldspars, especially certain varieties of them, yield baryta and lime for veinstone, while their liberated silica yields the quartz.

Thus, in these little minerals so common in nearly all rocks, especially those associated with our ore deposits directly or indirectly, we have all the elements necessary for the metals and the veinstone of veins and ore deposits, near at hand in the adjacent rock, without having recourse to the deep ignited regions of the earth, as required by the "igneous" and "sublimation" theories of the origin of veins.

"Organic matter is sometimes present in veins in the form of graphite and anthracite, it also forms the coloring matter of smoky quartz, fluorspar, etc. This occurs when the amount of organic material originally present has been more than sufficient to transform the metallic sulphates into sulphides."

In the depths and near the surface of the Bassick mine at Silver Cliff, Colorado, a substance resembling charcoal is found.

As lodes occur both in crystalline and semi-crystalline rocks, and also in rocks derived from these, such as sandstones, ores may be derived from the incompletely decomposed remains of metalliferous silicates such as mica, hornblende, etc., from the original crystalline rocks such as granite, or from solution products from older veins, or from traces of metals which are found in sea water.

Copper and gold have been detected in the waters of the Mediterranean.

In gypseous deposits of ancient seas copper is sometimes present.

In the red Trias sandstones of South Park, which were doubtless deposited in inland seas or estuarine formations, copper stains are common. Copper is similarly found in modern estuarine muds. Stratified rocks such as sandstones, that have been formed by the sea, consist of the debris of older crystalline rocks such as granite, which contain, as we have said, both the elements of the heavy metals in their constituent minerals and also in veins in their mass, hence is not surprising that we find copper stains in the Trias conglomerate, and at Morrison we have even found large crystals of galena in the boulders composing the conglomerate. Copper and zinc again have been detected in clay slates of marine origin.

Some strata possess a composition enabling them to decompose metalliferous solutions derived from other sources more readily than others, and re-deposit their contents in the form of ores. Limestone, for example, not in itself a metalliferous rock, seems a favorite receptacle of ores or ore solutions from other richer or ore-generating rocks.

ASCENSION THEORY.

Lodes were formed in part only of minerals dissolved out of the adjacent country rock. The chief portion of the material was derived from greater depth by solvents circulating through the fissures, sublimation assisting either with or without steam. The increased heat and pressure due to greater depth enables the solution of different vein-forming substances and minerals to be deposited in all parts of the fissure of which the constituents do not exist in the rocks or the immediate vicinity.

These solutions will, under the pressure, penetrate deeply into the surrounding rocks, and impregnate them with metalliferous minerals, also softening and decomposing the rocks to a considerable distance from the lode, or they may cilicify the cheeks of the fissure.

"Waters of solvent powers, increased by high temperature and pressure, percolating through rocks containing heavy metals will gradually remove them by lixivation, together with other mineral substances. These will again be deposited upon the sides of the fissure in proportion as the solvent powers of the mixture become lessened by diminishing temperature and pressure."

Minerals diffused through rocks near the surface may be removed by solutions which, penetrating into vein fissures, have mingled with the waters circulating through them. Deposits akin to those of true veins are at present being formed by the action of hot mineral springs. In the Steamboat Springs of Nevada such mineral veins are in process of formation. These springs issue from extensive fissures, which are being filled with silicous veinstone carrying oxide of iron and manganese, sulphides of iron and copper and metallic gold.

They also exhibit the banded structure so frequently observed in veins. A tunnel has been driven intersecting, at a great depth, one of the fissures formed by these springs, and a banded vein was found of quartz-carrying cinnabar. Sulphur is also found in these deposits and occurs in the old auriferous reefs of Australia and in some of the mines of Redcliff. Sulphuretted hydrogen may account for the formation of certain metallic sulphides in veins.

ORIGIN OF LEADVILLE ORE DEPOSITS.

The Leadville ore deposits have been the most thoroughly investigated by the U. S. Geological Survey under Mr. S. F. Emmons, of any of the mineral deposits of Colorado, and as the results of the investigation have a bearing upon many similar occurrences of minerals in the Rocky Mountains, we give an epitome of his views.

"The ores are deposited for the most part in the 'blue limestone' of the Lower Carboniferous. As the ores were deposited by water solutions, the soluble limestone beds would be more easily acted upon by solutions than the sandstones and shales composing the other rocks of the neighborhood which are less susceptible to percolating water. The Paleozoic formations in America are the principal repositories for lead and silver ores, not by reason of their geological age so much as by their containing such a quantity of soluble limestones, and being physically as well as chemically favorable for the reception of mineral solutions.

The physical, structural conditions of Leadville are particularly favorable to the concentration of percolating waters in the blue limestone. Great intrusive sheets of porphyry follow the limestone persistently, principally on its upper surface. This porphyry is very porous, and full of cracks and joints, affording ready channels for water from above, and also channels for ascending water from below along the walls of the fissures, through which it is erupted. Such waters passing through a medium of different composition would be ready for a chemical interchange with the limestone."

COMPOSITION OF ORES.

The ores were deposited originally as sulphides. This is shown by the fact that the oxidized ores near the surface pass down with depth into sulphides. In Ten-Mile district these oxidized ores are seen to result from the alteration of a mixture of galena, pyrite, and zincblende. There is very little gold in the average Leadville ores; what little there is comes from the Florence mine (native gold), and from others where it is associated with pyrites. It is usually associated with porphyry rocks, and a porphyry commonly called pyritiferous porphyry shows gold to exist diffused through the pyrites disseminated through its mass.

Silver occurs as chloride, a secondary condition, its original condition probably being sulphide.

Lead occurs as carbonate and sulphate. and deep in the mines as sulphide. Specimens are common of galena nodules surrounded by a thin coat of sulphate, and that again by a coat of carbonate, showing the order of transition from sulphide to sulphate and thence to carbonate.

In the Iron mine native sulphur occurs as an alteration product of galena.

Iron and *manganese* constitute rather a gangue material than an ore. They are hydrated oxides and protoxides. The iron was originally deposited as sulphide or pyrites, but has been wholly transformed by oxidation.

Zinc is not common, but occurs as calamine (zinc silicate) in needle like hairs and white crystals in cavities in the mines. Its original form was zincblende (zinc sulphide), as shown in the Ten-Mile district.

The earthy minerals, alumina, lime, silica and magnesia, are in fair proportions, as might be expected from ores which are a replacement of limestone in close connection with porphyry. The alkaline element among the ores might also be traced to the influence of the latter rock.

The agents of alteration were surface waters, which contain everywhere carbonic acid, oxygen, organic matter, chloride of sodium (common salt), and phosphoric acid. The rocks through which these waters passed, such as porphyries and limestones, were found to contain phosphoric acid and chlorine, while organic matter exists in the blue limestones, and in the overlying shales and sandstones are many carbonaceous beds and even beds of coal. Water passing through these rocks would take up all these elements and be ready for chemical reactions.

Galena (lead sulphide) is much richer in silver than its alteration product, carbonate of lead, or cerussite. On Carbonate Hill the carbonate averages 40 oz. silver, the galena is 145 oz. to the ton. But galena is harder of treatment.

Silver is found at times disseminated through vein matter and country rock, without the presence of lead, proving that during alteration silver was removed farther from its original condition and more widely disseminated than lead.

Outcrop deposits have proved in many cases richer than those at depth. The deposits near the surface have been the refined, concentrated remains of larger bodies gradually removed by erosion as the alteration by surface waters went on. The baser and more soluble metals have thus been removed in solutions, leaving behind the more valuable and perhaps less soluble metals in new and richer secondary combinations.

Kaolin or *Chinese talc*, which occurs both along the line of contact and between the porphyry and limestone and also in the heart of the vein material, is a decomposition product from porphyry. It consists principally of hydrated silicate of alumina, doubtless derived from the feldspars of the porphyry, perhaps at the time when acted upon by sulphurous waters which brought in the *original* ore deposits.

Calcite occurs incrusting recent crevices and lining recent cavities, but in small amount.

Barite or heavy spar is common, generally associated with chloride of silver and with manganese, and is locally recognized as a sign of rich ore.

ORE DEPOSITED AS SULPHIDES.

We have already stated that depth in the mines away from the surface waters proves this to have been the original character of the deposits.

Under what reaction could this occur?

Sulphides of the heavy metals may be precipitated from various solutions.

1st. Where they exist as sulphides, by sulphides of the alkalies and alkaline earths.

2nd. Where they exist as carbonates and sulphates coming in contact with solutions containing alkalies and sulphuretted hydrogen.

3rd. Where they exist as sulphates, which in contact with organic matter are reduced to sulphides.

Metallic sulphides are soluble in water containing alkalies or sulphuretted hydrogen or silica, and in waters containing alkaline carbonates.

Solfataric or hot waters, arising from the heated depths, contain sulphuretted hydrogen, alkaline sulphides, and carbonates.

If the metals of these deposits came up from the heated depths or were derived from pyrites and galena in neighboring rocks, then the iron and lead were brought in as sulphides. This would seem to involve that the carbonates and sulphates of the limestone should have been dissolved out and carried away before the sulphides were deposited, and this would involve the popular pre-existing cavity theory (which Mr. Emmons believes to be incorrect). Probably, however, the dissolving out of the former so immediately preceded the deposition of the latter, that the process was an interchange of substance for substance, or the commencement of a change from sulphide to sulphate may have taken place in presence of the carbonate, and the sulphate been immediately reduced to sulphide again by organic matter, and there is evidence that locally the dolomite limestone has been directly replaced by sulphides, by zincblende, pyrite and galena in pseudomorphs after calcspar and dolomite.

In contact with dolomite containing organic matter the sulphates would be reduced to sulphide with the formation of carbonic acid. The waters thus charged with carbonic acid would dissolve and remove the carbonates of lime and magnesia, which would be replaced by metallic sulphides.

Any excess of sulphuric acid would form soluble sulphates of lime and magnesia, which would also be carried away. If these sulphates were reduced to sulphides they would render the waters more capable of dissolving out the dolomite. The metals might have been taken up in the form of sulphates by waters percolating through rocks, where they might have been brought into this combination by the oxidation of sulphides, or by decomposition of silicates, or in this transition the sulphates may have been reduced to sulphides by contact with organic matter before reaching the locality of deposit.

Sulphide of barium would be precipitated as sulphate of baryta in contact with limestones.

Silica brought in by waters containing alkaline carbonates, is soluble, and might form silicates of the alkalies, carbonic acid waters carrying away earthy carbonates.

Later, the combined alkalies were replaced by oxide of iron, and in part dissolved out, leaving free silica.

MODE OF FORMATION.

The Leadville ores, like most others, were deposited from water solutions by a metasomatic interchange, *i. e.*, substance exchanged for substance with the limestone, and lastly or originally, as sulphides.

Mineral matter is carried from one place to another within the earth's crust by heat and water, or these combined. Metasomatic interchange of metal for limestone and the removal of dolomite could only have been produced by water. The ores were *not* deposited in *pre-existing cavities*, but are a replacement of the country rock, *i. e.*, dolomitic limestone.

The ores grade off gradually into the material of the limestone, without a definite limit, as would have been the case if the limestone had been previously caverned. The only limiting outline to the ore bodies is that formed by the contact porphyry.

Fragments of unaltered limestone are found entirely enclosed within the ore bodies, and ore bodies often occupy the entire space for long distances between two horizontal sheets of porphyry, which space further on is occupied by the limestone. (This is well seen in the Colonel Sellers mine.) Examination of ores and veinstone show lime and magnesia not in the crystalline condition they would have, had they been brought into a pre-existing cavity and deposited, but in the same granular condition in which they exist in the country rock.

"The deposits in rocks other than limestone consist of metallic minerals and of altered portions of the country rock, in which the structure of the latter can sometimes be still traced, and are not the regular layers of matter foreign to the country rock, which results from the filling of a pre-existing fissure or cavity by materials brought in from a distance and deposited along the walls.

In the Ten Mile district the arrangement of the particles of the original rock is frequently seen to be preserved in the metallic minerals which maintain a certain parallelism with the original bedding planes in the lines defined by minute changes in these minerals.

The common character of caves which have been dissolved out of limestone, is that their walls are coated with a layer of clay which has been left undissolved by the percolating waters, and these walls have a peculiar surface of little cup-shaped irregularities from which also stalactites frequently hang. There is also an accumulation at the bottom of the cave of fragments of limestone fallen from the sides of the roof. None of these characteristics are found associated with the ore re-placements.

Also, when mineral matter is deposited in "pre-existing cav-ies" it takes the form of regular layers parallel with the walls of ne cavity, as is beautifully shown in geodes lined with a success-ion of zeolites or with layers of chalcedony, opal, and quartz.

No such successive arrangement in layers is found in the Leadville ore bodies.

Again, could such large, open cavities have existed for long istances without support, between the layers of porphyry? Vhy did not these porphyry sheets close together? And urther, how could such extensive cavities have been formed and ept open under a pressure of 10,000 feet of rock, which ne geology of the region shows to have existed above the eposits, at the time they were being formed? Such cavities as ve do find in the region are all of very recent origin, cutting hrough both limestone and ore bodies, and have been hollowed ut by surface waters more recent even than those which pro-luced the secondary alterations in the ore bodies.

ORIGIN OF METALLIC MINERALS.

Ore deposits have been deposited from solutions through the gency of water, with or without the assistance of heat.

Within the rocks forming the crust of the earth there is a onstant circulation of waters, carrying more or less mineral natter in solution, and no rock is absolutely impermeable.

There are upward and downward currents. The latter are urface waters sinking by gravity. The former are the same vaters rising under the influence of the heat of the earth. The lirection which such waters take will depend upon the struc-ure of the rock mass through which they pass, whether upward, lownward or laterally.

Waters filling capillary passages and minute fissures will seek arger channels in joint, fault, and stratification planes. Water arrying mineral matter in solution along such channels will leposit it where the rock favors chemical precipitation or inter-hange, and this will take place most where there is some interrup-ion in the flow, as rapid waters deposit less readily than those vhose movement is slow.

SOURCE OF METALS.

"The ultimate source is a matter of speculation, like the nebular hypothesis, by which the earth is supposed to have arrived at its present condition as the result from the gradual cooling of an incandescent mass, and as the specific gravity of the crust is much less than that of the whole mass of the earth, it has been inferred that the heavy metals must be in much larger proportion in the interior of the earth than in the rocky crust," (though this greater specific gravity might be also accounted for by the rocks of the interior being much more tightly packed by pressure than those near the surface).

"Volcanic emanations and hot springs contain metallic minerals, so also do the waters of the ocean. But we know not from what depth the former came, nor from what source the latter derived them. As circulating waters, take up and throw down their metallic contents under varying conditions, the same material may have been deposited more than once and in more than one form, since it reached the rocky crust. The ores do not seem to have ascended from below, for the geology of Leadville shows that the ores were deposited beneath a thickness of not less than 10,000 feet of strata and an unknown depth of sea-water. If they had been deposited from hot ascending solutions as the result of a relief of pressure, which would favor precipitation, the deposit would be found in the upper part of this mass of rock rather than at its base.

The sedimentary beds at the time of deposit were horizontal and undisturbed. There are no channels discovered through which the ore could have ascended, the eruptive rocks being horizontal and parallel with the stratification, hence the ore deposits were not formed by ascending waters.

The principal water channel at the time of deposition was the contact of the upper layers of the blue limestone with an overlying sheet of porphyry, and from this surface they penetrated downward into the mass of limestone. The currents were descending by gravity rather than ascending by heat.

Percolating waters circulate freely through eruptive rocks owing to their porous character, and their tendency to jointage and fracture, the results of cooling and weathering.

In sedimentary rocks the bedding planes are the natural rses for water.

Water would thus descend through the vertical joints of the rlying porphyry, and would turn off horizontally on or between bedding planes of the underlying limestone into which they uld eat their way gradually downwards, through jointage cracks l other weak points.

According to the "lateral secretion" theory, which seems rest to the truth, all the substances contained in the lodes have n derived from the adjoining rocks. Sandberger and others e satisfactorily shown this to be the case, and that all metals nd in veins can also be found in minute quantities in the con-uent minerals such as mica, hornblende, augite, and other cates of the adjacent or country rock. And, rather singularly, considers the metals are derived more from these silicates than m the pyrite so commonly diffused through eruptive rocks, nsidering, moreover, that the latter are not original constituents these rocks.

The results of a minute analysis of the rocks adjacent to the bodies at Leadville, viz., porphyry and limestone, selecting gments the most remote from ore currents and the purest ob-nable, show baryta and lead to be contained in the feldspars of porpyhy. Gold and silver also exist in minute quantities in elements of the porphyry, especially of that variety called ritiferous porphry, and those porphyries and diorites which con-ned the greatest amount of basic elements as a rule yielded greater proportion of the heavy metals. The percentage these metals is very small apparently, but when we consider enormous amount of the porphyries, (some even 1,000 feet ck,) actually present, not to mention those that have been re-ved by erosion, we see that this small percentage, if concen-ted, would adequately account for all the metal found in the adville region, with a good deal yet to spare, minutely dissem-ted or chemically combined with certain earthy minerals con-uting the elements of the great bodies of porphyry.

On the other hand the dolomitic limestone and other sedi-ntary rocks were found in themselves to show no original heavy tal elements.

The metals then, came from the porphyry and were deposited only in the limestone. Some of them, too, may have ascended through the dykes that were feeders to the great horizontal porphyry sheets."

Part III.

PRINCIPAL COLORADO MINING DISTRICTS.

BOULDER COUNTY.

The mines are situated on the Eastern slope of the Colorado ge. The mining district is about thirteen miles long by four en wide (not including Caribou Hill).

GEOLOGY.

Along the foothills adjoining the plains is a series of "hog-ked" ridges formed by the upturned floor of the prairie, con-ng of Triassic, Jurassic and Cretaceous strata, resting on the hæan granite core of the range.

These upturned sedimentary beds of sandstone, limestones, s and shales form a fringing belt, varying in width and dip, ig the entire extent of the Eastern foothills.

South of Boulder their dip is almost vertical, forming near th Boulder Cañon a magnificent peak 3,000 feet above the ns.

The Upper Cretaceous or Laramie group contains valuable beds, whose outcrops, owing to erosion at Boulder, are some es out on the plains.

These hogbacks also supply excellent building stone, flag-es, fire-clay and lime.

They are barren, however, of precious minerals, both here generally along the Eastern foothills.

The Archæan granite rocks immediately adjoining the plains also, as a rule, been found to contain but few valuable erals.

A few copper stains and some local stains and deposits of copper are nearly all that is found. It is not until the range has been penetrated for a distance of several miles that productive deposits appear.

In Boulder County we have the nearest mines to the plains, they being not more than two miles distant.

The Archæan rocks consist principally of a granite-gneiss, showing indistinct signs of primitive stratification. This is intersected by veins of pegmatite, or very coarse, crystalline, and sparry granite, varying in width from a few inches to 40 or 50 feet. Their composition is the same as granite, consisting of white feldspar and quartz, with very little mica; in other words, granite in a coarser and more crystalline, sparry condition than the adjacent country rock and with less of its mica.

Two of these veins, the Maxwell and the Hoosier, are strong and well defined, traversing the district for several miles. The Maxwell runs East of North, crosses the road two miles from Boulder on the way to Sunshine, and is easily visible from its reddish, white and rusty color. It carries pyrites and tellurides. The Hoosier vein, or rather gangue, forms the western limit of the telluride belt, is 30 feet wide, and runs through Gold Hill in a direction East of North. It carries silver ore and gray copper.

The Telluride belt underlies the Magnolia, Sugar Loaf, Gold Hill and Central districts. Eruptive rocks are scarce in this belt, but "pegmatite" veins abound.

West of this region enormous masses of eruptive rock occur, and tellurides are not found.

In the Caribou district are rich silver ores, carrying 300 to 1,500 ounces silver to the ton. In the Ward district veins carry free gold, with iron and copper pyrites, which have a general direction East and West, while the others are more nearly North and South. Of eruptive rocks, that which forms the Sugar Loaf, a conical hill between Four-Mile and Boulder Creeks, is a fine-grained porphyritic rock, of a grayish color, showing small, white feldspars, black mica and hornblende, and crystals of titanic iron, with a little augite. The crystalline ground mass in which these crystals are set consists principally of feldspar, with a little quartz. A similar rock is on Four-Mile Creek, showing large feldspar crystals. This rock is a massive eruption of considerable extent. A dense black rock not unlike basalt occurs east of the Sugar Loaf, in a dyke, and is called diabase.

At Jimtown a quartz-diorite dyke occurs, of light color, containing much hornblende and titanic iron, running nearly through the street of the village. The cliffs at Jimtown, over 500 feet high, are quartz porphyry, of a white color. It consists mainly of large crystals of quartz and feldspar, set in a fine-grained crystalline ground mass or paste.

MINES.

Boulder mines are celebrated for the occurrence of Telluride minerals, some of the richest and rarest ores occurring in nature. The Telluride belt occupies the eastern part of the district, and extends to within a short distance of the sedimentary "hog-backs." It comprises the Magnolia, Sugar Loaf, Central and Sunshine districts. West of this belt no tellurides occur.

In Caribou district the ores are rich argentiferous galena, with many varieties of other rich ore, stephanite, proustite, and others. In the Ward district pyrites abound, and where it is decomposed free gold is found. The pyrites, though gold-bearing, is difficult of reduction.

The Boulder district contains very rich ores, yet development has been irregular and production uncertain, due partially to the irregular manner in which the ores occur. Of late, mining has been resumed at Caribou, with prospect of steady output.

The veins, that is the "pegmatite" gangues, are called true fissures, and stand at a high angle and are often very wide, but the rich ore is concentrated in thin streaks and not very continuous bodies. Of the character of the fissure veins Mr. Emmons says: "If the term 'true fissure' means a vein which occupies what was once a deep-seated, wide-gaping fissure, filled in by vein matter and ore, coming from unknown depths, and distinct and foreign to the material of the adjacent country rock, there are no such true fissure veins in this district," and we might go further and add nor in Colorado generally.

The gangue or vein material is simply an alteration of the adjacent granite or gneissic country rock, as testified by its composition, which is quartz, feldspar and some mica. This is impregnated with rich mineral, whose source we may venture to say is not far to find, microscopically or chemically diffused in an adjacent country rock of porphyry, and concentrated in the sparry material.

This impregnation has taken place either along the contact of an eruptive porphyry rock with the country rock granite, or else in a pre-existing vein of pegmatite, or along some fault or jointing plane in the country rock itself, which has been favorable to the concentration and precipitation of metallic minerals from their solutions. This account will fit many of the so-called "true fissure veins" in Colorado. The direction of the vein is generally between North-East and North-West, in the Ward district East and West. Their dips are mostly very steep or vertical.

TELLURIDE ORES.

The quartz or pegmatite gangue impregnated with telluride ore has generally a pale, bluish-gray and rather greasy appearance, streaked here and there with a dull, blackened, greasy stain upon which sometimes the true telluride minerals can be seen, such as sylvanite, which occurs in long, thin crystals of a bright, tin-like appearance. It is sometimes called graphic tellurium, because the crystals crossing one another assume the form of Hebrew writing characters. It is a telluride of gold and silver.

There are many varieties of telluride ores, some rich in silver, and others in gold, and some with both combined. When a piece of the gangue containing tellurium is roasted, the gold will come out in good-sized globules on the surface. This used in early days to be a much-coveted specimen for those who wanted to possess a piece of Colorado gold in the rock itself.

Hessite, petzite, Coloradoite, and native tellurium are among the varieties of tellurides.

Central District. The "Golden Age" mine, near Jimtown, is at the contact of porphyry and granite. The vein is 40 feet wide. The ore comes from a streak of white quartz, one to two feet thick, sometimes very rich in free gold. Pyrites also occur. Rich concentrations of ore are found at intervals, some ore as high as $30 per pound; average ore mills $20 per ton.

Gold Hill district is in the telluride belt traversed by the Hoosier gangue. Several of the veins cross the Hoosier gangue, and are richer in its vicinity. The Red Cloud's vein is 3½ feet wide. The ore was telluride at the surface, passing into auriferous pyrites in depth.

Sunshine, also in the telluride belt. Its ores are lower grade. Free gold and tellurides occurred on the surface, passing into pyrites with depth. The American, Grand View and others are among the principal mines.

Sugar Loaf, also in the telluride belt, is an enrichment of the Hoosier gangue, the gangue being pegmatite.

Magnolia district. In the Keystone mine is a narrow deposit, 6 to 7 inches wide, yielding Coloradoite (telluride).

Ward district is outside of the belt, and carries copper and iron pyrites bearing gold, some of which mills $60 per ton on an average.

Caribou. The Caribou mine has yielded a great deal of silver. Its ores are a mixture of galena, chalcopyrite and zincblende, occurring in gneiss near a dyke of eruptive diabase. The Caribou mine has produced two millions of dollars.

The "No-Name" is said to cross and fault the Caribou. The ores are silver-bearing, but also carry gold. Ores are silver glance, stephanite, gray copper, argentiferous galena, copper pyrites. Native silver is common, also some ruby silver. Copper pyrites carry more gold than silver.

Prof. van Diest considers that the granite rocks near Boulder are thrown into a series of parallel folds, "first a great fold following the continental divide, prominent near Gold Hill; another near North St. Vrain, and a third between Middle and South Boulder. Also, two prominent side folds cut these main folds diagonally, one running from Ballarat to Jimtown, the other from Sugar Loaf to Gold Hill. The telluride veins run along the slopes of these folds."

He appears to associate the veins with cracks and fissures coinciding with this folding. "Some of the main fissures being filled at once by porphyry dykes, the others more gradually by vein material." "The veins," he says, "occur along, on, and near these dykes, along lines at the junction of the more massive granite with the stratified gneiss, along and between stratification planes of schist, and along the joint planes of granite."

He attributes the veins to percolating alkaline waters dissolving metalliferous material and veinstone from the surrounding rocks. Alkaline springs, he observes, still exist in the neighborhood, as they do in the mining district of Idaho Springs. "The veins occur where the foldings are abrupt, and the direction of the veins is parallel to the strike of the stratification. As a rule, the veins in Boulder County are not of great extent; a single vein can rarely be traced on the surface or beneath it for more than 600 feet. Before that distance is reached the vein spurs off into another vein, follows it for a while, and spurs off again into another.

"Where veins cross at a small angle or where a spur branches off from the main vein, accumulation and enrichment of ore takes place. There are two courses of veins, one East and West, the other North-East by South-West. The former system appears to be the oldest, as the latter faults it.

"The ore occurs in chimneys or pockets, with a good deal of nearly barren ground between. Small veins run parallel with each other for some distance, the interval filled with granite or pegmatite. Sometimes a vein pinches out entirely. The ore streak is from 1 to 20 inches wide, containing more hornquartz than the country rock. Some of the veins interlace like arteries in a body. Minute particles of pyrites (marcasite) often produce a dark stain in the telluride quartz. By moistening the stone the telluride minerals and pyrites appear distinctly."

GILPIN COUNTY.

The geology of the mines and veins of Gilpin County, which congregate around the vicinity of Central City and Black Hawk, resembles that of Boulder. The region consists of Archæan granite and granite-gneiss, penetrated by felsite and quartz porphyry dykes. The veins are here also only alterations of the country rock along certain planes, but do not occupy a once wide, gaping fissure. In some mines the vein material is a porphyry dyke. The vein of the Minnie mine is a felsite porphyry;

of the Cyclops mine, a quartz porphyry. Dykes of porphyry occur near the lodes or in contact with them.

The veins have been traced to a considerable depth, over 1,000 feet, and in length over 3,000 feet. The direction of veins is between North and South and North-East and South-West. The dip is nearly vertical.

The ores are a mixture of iron and copper pyrites, very little galena, and some zincblende. All carry more or less gold.

There is also a silver district in the northern portion. The diameter of the gold district, which is quite distinct, is not more than 1 ½ miles.

In the gold veins the richer ore occurs in streaks not over one foot wide, in a compact, fine-grained mass of pyrite, copper pyrites being richer than ordinary iron pyrites. The rest of the vein, often many feet wide, carries pyrite irregularly, disseminated through decomposed country rock. The bulk of these ores are difficult to treat and are milled, the loss being 40 per cent. higher in the unoxidized than in those completely oxidized.

The veins follow the cleavage planes of the country rock. These cut the stratificated planes at right angles, with a vertical dip. It is supposed that the porphyry dykes are older than the veins, as the cleavage intersects the porphyry equally with the other strata.

The interval between these mining districts and the plains, usually 20 miles or more, is commonly barren of precious minerals.

The Gregory, Bobtail, Burroughs and others are among the mines of note.

CLEAR CREEK COUNTY.

"The geology of this adjacent district is much the same as that of Gilpin county. The country rock is Archæan granite and gneiss, traversed by porphyry dykes. The fissure veins are also alterations of the country rock along a jointing or faulting plane and are frequently in direct connection with porphyry dykes which form either one or the other wall of the vein and sometimes constitute the vein material itself. In other cases the mineral vein is an impregnation of a pre-existing pegmatite vein in the gneiss."

"The ores are silver bearing and derived from argentiferous galena and gray copper. Where pyrites abound the ore yields both silver and gold. The rich ores are smelted. A large proportion is concentrating ore which impregnates the country rock at a greater or less distancefrom the main crevice, usually on the foot-wall side.

The porphyry filling or gangue of the Colorado Central vein assays 0.063 oz. of silver to the ton, and a trace of gold.

Georgetown, Idaho Springs and Geneva Gulch are the centers of the principal districts.

Geneva Gulch and Hall Valley though not in Clear Creek county belong to the same mineral belt."

Obsidian dykes occur in the Colorado Central vein parallel with the vein, which is a porphyry dyke, there is therefore a dyke of obsidian within an impregnated dyke of porphyry, and the richest mineral is close to that obsidian.

The Centennial has one wall porphyry, the other not found and the mineral lies close to and impregnates the porphyry, fading out in the same rock. The porphyry assays a fraction of an ounce gold and silver in the Centennial, and three to four ounces gold in the Colorado Central. Feeders come in, and the best ore is between the feeders, but not in the feeders themselves. The ores are copper and iron pyrites, and, near the granite, zinc and lead.

In the Colorado Central mine faulting seems still progressing. Mr. C. Gehrman tells me they are obliged to re-timber the mine every now and then in consequence of the foot-wall rising. Some of the Georgetown veins between walls are quite large, (from 50 to 100 feet,) but the pay streak, though rich, is small in proportion.

The Centennial vein is large and carries plenty of ore, but not of very high grade. There are three main porphyry dykes in the region with branches from them. The gold ore keeps near the porphyry and is an impregnation of it.

SUMMIT COUNTY.

"The high mountain portion of this county consists of Archæan granite rocks. But along the valley of the Blue river, fragmentary beds of the Silurian, Carboniferous, Triassic, Jurassic and

Cretaceous periods occur which have escaped erosion, relics of a former connection of the seas which filled the South and Middle Parks.

These rest on the Archæan of the Park Range, and are repeated on its West side, the park range having been lifted up by the great fault movement so well defined in the Mosquito range.

Along the upper portion of Eagle river, Silurian and Carboniferous beds appear, dipping North and resting on the Archæan granite of the end of the Sawatch range, associated with these are a great many eruptive porphyry rocks, the latter throughout this district show a marked connection with the relative richness in size of the ore deposits which occur all the way from the Archæan to the Triassic.

At the head of the Blue River the Silurian, Carboniferous and Triassic formations have been much traversed by eruptive sheets, whose heat has caused metamorphism of the sedimentary beds. The beds are also much faulted, and the principal developments center around Breckenridge.

The "Helen" mine in French Gulch has ore as an impregnation of quartzite for 45 feet in width. The ore is free gold with some silver. The quartzite is rusty by the leaching out of the auriferous pyrites it originally contained. In the McKay mine argentiferous galena and carbonates of lead occur near an overlying bed of porphyry in a sedimentary rock."

The Monte Cristo mine on Quandary Mt., has a deposit of low grade galena and zinc-blende, impregnating Silurian quartzite, its average is 15 oz. to the ton.

Veins occur at several points in the Archæan granite of the Mosquito range, but so far unimportant.

In Ten-Mile district the ores are mainly in the Upper Carboniferous limestones and sandstones, a higher horizon than at Leadville. This is an area of wonderful eruptive activity abounding in intrusive sheets and dykes of porphyry. The ores are rather low grade and refractory, consisting principally of pyrites mixed with zinc blende. Most of the ore bodies occur in thin beds of limestone at their contact with a micaceous sandstone, more rarely at contact with a bed of porphyry or impregnating a dyke of porphyry. The last is best seen at the Pride-of-the-West on Jacques Mt. The Robinson is the principal mine, its ore is high grade argentiferous galena, associated with pyrites and zinc-blende, it occurs near the surface of a bed of gray limestone over-laid by white micaceous limestone, dipping N. 17°. The ore is a re-placement of the limestone. The upper layer, consisting of pyrites and white mica, is a replacement of the overlying sandstone and is worthless. Below this the ore consists ot galena and pyrites, extending to irregular depths in the limestone and in the larger bodies occupying its whole thickness. The greatest width of the ore chute, 100 feet, has been traced 1,000 feet following the dip. A crack or fault plane in the roof follows the line of the ore body and probably furnished the channel through which the ore solutions reached the limestone, as pyrites extend all through the fissure.

On Elk Mountain ore is found in a thin bed of limestone at a higher horizon still than the Robinson, but it is poor in silver and it even extends up into the Triassic red sandstones. The "Pride-of-the-West," on Jacques Mountain, is a dyke of porphyry impregnated with baryta and ore.

On Eagle River, near Redclift, argentiferious galena and carbonate of lead with iron oxide occur between limestone and porphyry or between limestone and quartzite. The limestones are carboniferous."

PARK COUNTY.

The basin plain of South Park is covered by sedimentary rocks of Triassic and Cretaceous age underlaid by Carboniferious and Silurian formations. These slope up to the crest of the Mosquito range on the West, but are apparently cut oft abruptly against the Archæan granite on the East, probably by a fault. The coal beds of the upper Cretaceous occupy a portion of the center of the park around Como and stretch Southward to the Platte River.

Near Hamilton are deposits of hematite iron. Salt springs occur in the Southern end of the park, issuing from Triassic red sandstones.

In the North-East corner of the Park, in the granite rocks, are the Hall valley and Geneva districts, a continuation of the

Clear Creek silver belt system. In the "Whale" mine the gneiss is intersected by numerous veins of pegmatite. The lode runs North-East and South-West, and dips at 65°. It is a thin vein of baryta and quartz, with irregular bunches of galena and gray copper, the latter very rich in silver. The crevice is 5 to 10 feet, but the vein proper, or pay streak, is from an inch to three feet wide. The altered walls are impregnated with pyrite, galena and zincblende. The principal mineral developments are along the eastern slope of the Mosquito range, and are derived principally from Silurian and Lower Carboniferous rocks. The order and succession of the lower, older or Paleozoic rocks composing this range are here seen, together with their average thickness.

First granite, forming the base and usually found at the bottom or on the cliffs of the deeper cañons; upon this rests:

			FEET.
Paleozoic.	Silurian.	Cambrian quartzite	200
		Silurian white limestone	200
	Carboniferous.	Lower Carboniferous blue limestone . . .	200
		Middle Carboniferous, or Weber grits (sandstones and quartzite)	2,000
		Upper Carboniferous limestones, reddish sandstones and conglomerates	1,000
		Total	3,600

In some localities the total will reach 4,000 feet. These formations have been traversed by eruptive quartz porphyry, porphyrite dykes and intrusive sheets. The dykes occur principally in the Archæan, but the intrusive sheets are many, spread out between the quartzites and limestones of the Silurian and Carboniferous.

The connection between the eruptive masses and deposition of ore is very marked. "The ore bodies are a concentration of the metallic minerals originally disseminated through the mass of these eruptive porphyries, and now deposited along their plane of contact with the sedimentary beds, and extending more or less into the mass of the latter."

On Mts. Lincoln and Bross, in the principal mines, such as the Moose, Dolly Varden, Russia, and others, the ores are mainly argentiferous, yielding galena and its products of decomposition, viz., carbonate of lead (cerussite) and sulphate of lead (anglesite), with chloride of silver. Barite (heavy spar) is a common gangue or veinstone, especially in the richest parts of the mine. Iron pyrites, decomposed and passing into a hydrated oxide of iron, together with a black oxide of manganese, give to the ore its rusty and black look.

The deposits occur in irregular bodies or pockets, often of great size, in the blue limestone, near its upper surface, but not always easy to find or follow. This limestone was originally covered by a sheet of quartz porphyry, which has been locally removed from the ore deposits, but exists in various parts of the Mt. Lincoln peak. The quartz porphyry is the variety called Mt. Lincoln quartz porphyry, and recognized by its large crystals of feldspar. The age of this porphyry is probably as late as the Cretaceous. As in the Gunnison, it is found breaking through rocks of that period. In the Dolly Varden mine the ore occurs in the limestone at contact with a vertical dyke of white quartz porphyry. In the Fanny Barret mine, on Loveland Hill, rich deposits of galena and anglesite occur in a vertical fissure or jointing plane traversing the limestone at right angles to its dip.

In Buckskin Gulch the Phillips mine is an immense mass of gold bearing pyrites, deposited in beds of Cambrian quartzite near a dyke of quartz porphyry.

The Criterion, on the cliffs of the gulch consists of large cavities in quarzite, occupied by both oxidized pyrites and galena near a green porphyrite dyke.

The Colorado Springs mine has rich deposits of galena in the white Silurian limestone in close relation to dykes of diorite and quartz porphyry.

The London mine in Mosquito Gulch has two strong veins of pyrites carrying both gold and silver, the gangue of one is quartz, of the other calcite. They occur in the limestone in connection with an intrusive bed of white porphyry. These veins stand in a vertical position, the beds which contain them being turned up abruptly against the great London fault, by whose movement the Archæan granite rocks forming the eastern half of London Mountain are brought up into juxtaposition with the Silurian and Carboniferous beds at its Western point. As we go South along the Mosquito range the intrusive porphyries diminish in extent and with them also the mineral deposits.

In the Sacramento mine rich bodies of galena and rich decomposed minerals have been found in a series of pockets. Some of the cavities or caverns are empty, others contain sand and decomposed pebbles of ore, and others rich deposits. These deposits are not easy to follow with any certainty, open fissures lead up to the surface of the limestone. The limestone was originally capped by quartz porphyry which doubtless supplied the ore.

Placer deposits. The mountains bordering South Park owing to great elevation, have been much exposed to glacial action. An enormous amount of detrital material has thus been accumulated in the valleys in the form of moraines, which, when rearranged and concentrated by water, have formed valuable placer deposits.

The first placer gold was discovered in Tarryall creek in 1859, and in those days produced rich results.

Near Fairplay an immense amount of this material probably resulting from the influence of several glaciers, is cut by the Platte river exposing loose material for fifty feet. This has been worked for many years by sluice mining.

At Alma a gravel bed sixty feet deep is exposed on the banks of the stream which is at present successfully worked by hydraulic mining. Gold in flakes and small nuggets has been found all through this mass in paying quantities, but the richest deposits are found in the crevices and cracks of the bed rock, which consists of a jointed bed of Carboniferous sandstone dipping gently.

It is customary to rip up this sandstone for four or five feet until a bed of more impervious clay is reached. No gold is found below this second floor. The gold is collected by quicksilver thrown into the flume daily, and afterward separated from the quicksilver by retorting it.

LAKE COUNTY.

The Western boundary of this little county is the Sawatch range of Archæan granite, penetrated by dykes of porphyry. The slope of the Mosquito range on the East and the hills on the North, forming the water shed between the Grand and Arkansas rivers, have a basis of Archæan granite and gneiss more or less covered by patches and remnants of the Paleozoic formations, *i. e.* Silurian and Carboniferous, which have escaped erosion.

Their lower position relative to corresponding beds on the eastern or South Park side of the Mosquito range is due in part to faulting, and in part to folding of the beds.

Within these Paleozoic formations, these beds of quartzite and limestone, there is an enormous development of eruptive rocks principally quartz porphyries partially occurring as dykes but generally as immense intrusive sheets following the bedding plane of the sedimentary rocks.

Glaciers have been at work also in this neighborhood. A huge "mer de glace" occupied the great valley of the Arkansas to whose bulk numerous side glaciers contributed, these glaciers have carved and sculptured the mountains. In the flood period following the first glacial epoch a lake was formed occupying the head of the Arkansas valley. The stratified gravel and sand beds which were deposited at the bottom of this lake now form terraces bordering the valley of the Arkansas river. These beds, known as "wash" or placer grounds, yield gold and are open to further development. Leadville is the center of the mining district, the ores are agentiferous galena and zincblende. They are smelting ores. Their value is increased by their having been oxidized, the lead occurring as carbonate, the silver as chloride in a clayey, or else siliceous mass of hydrated oxides of iron and manganese.

The ore is principally confined to the horizon of the "blue" or lower carboniferous limestone, covered by an intrusive sheet of "white Leadville quartz porphyry." The ore bodies occur not only at the immediate contact of these rocks but extend down in irregular pockets and chambers into the mass of the limestone, sometimes to a depth of 100 feet. Sometimes the ore completely replaces the limestone between two sheets of porphyry as in the "Col. Sellers mine," Chrysolite, Little Pittsburg, and on Fryer Hill. A few ore bodies occur, carrying more gold than silver, found at other horizons, usually as "gash" veins running accross the stratification or along bedding planes. Such are the "Colorado Prince" in quartzite, the Tiger and Ontario in the Weber grits of the Middle Carboniferous.

The "Printer Boy," one of the oldest mines, has produced a
d deal of gold, found as free gold associated with carbonate of
and galena, passing down, as is usual in gold mines, into
tered auriferous iron and copper pyrites, which occur in a body
uartz porphyry along a vertical cross-joint or fault plane in
porphyry. The gangue is a white clay resulting from decom-
tion of the quartz porphyry and though the clay ore is rich,
ows no minerals to the eye.

The Paleozoic formations together with the intrusive porphyry
ts sandwiched in between them, have been compressed into
le folds, and where the fold was at its greatest tension, a
es of parallel faults have occurred having a general North and
th direction, their uplifted side is generally to the East.

The prevailing eruptive rock is the "white Leadville porphyry,"
urring generally above the blue limestone but also in places
w it and at other horizons.

There are also other intrusive sheets of different varieties of
rtz porphyry. The ground is generally buried beneath a
dred feet of glacial moraine material, locally called "wash."

The general geology of the South Park and Leadville region
been so elaborately traced by the labors of the U. S. Geolog-
Survey that we cannot do better than give an abstract of
r report in this connection:

LOGY OF THE MOSQUITO RANGE AND LEADVILLE AND SOUTH PARK REGION (S. F. EMMONS).

The Rocky Mountains in Colorado consist of two parallel
ifts of Archæan rocks of granite, gneiss, etc., with conformable
es of geological formations, from Cambrian to Cretaceous,
ing upon their flanks, the later Tertiary alone being uncon-
mable and resting on top of the upturned Cretaceous.

The eastern uplift is called the Colorado or Front range, the
tern the Park range. The depressions between them are
ed Parks.

The unconformity between the horizontal Tertiary and the
ifted Cretaceous and other beds shows that the great uplift of
ranges took place between the close of the Cretaceous and
deposition of the Tertiary.

The beds which we find uplifted and resting on the flank these ranges do not appear ever to have covered or envelop the ranges of granite, but the latter formed the shore line islands against which these sedimentary strata were deposit and finally when the whole granite mass was uplifted the sho line deposits were lifted with it and appear now as a fri around the masses, which has suffered much since by denudati

The Colorado range was the most extensive of these anci land masses, extending from Pike's Peak to the boundaries of State, 150 miles in length by 35 to 40 in width. North South of this area it was continued by a series of islands and su merged reefs to the Black Hills of Dakota on the one hand to the Territory of New Mexico on the other.

THE PARKS.

The present valleys of the North, Middle and South Pa were submerged in Paleozoic and Mesozoic times by the s and also in Tertiary times by fresh-water lakes. They forme connected series of bays and arms of the sea and fresh-wa lakes, as shown by the sediments of those eras still found in the

In Paleozoic times the outlet of the North Park was towa the North, of the Middle Park toward the West, and of the Sou Park to the South.

Up to the close of the Cretaceous the North and Mid Parks were connected, forming a single depression. The prese mountain barrier between the Middle and South Parks did extend as far as their western boundaries, and a water connecti lay between them.

The waters of the South Park extended westward to the flan of the Sawatch range.

In Tertiary times the Parks had been raised above the oce level and were occupied by fresh-water lakes. Sedimentary be were deposited in them, much of which have been denuded The western boundary of the Park area consisted of two disti ridges or islands, forming a general line of elevation parallel w the Front range.

These are the Park range proper, on the West side of t

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North Park, and the Sawatch range, now separated from the South Park by the Mosquito range.

Between these was the Archæan mass of the Gore range, which formed, with the southern extremity of the Park range, the western wall of the Middle Park.

The present boundary of the South Park on the West is the Mosquito range.

Before the Cretaceous no Mosquito range existed. The rocks now forming its crest rested at the bottom of the sea.

The Sawatch range is the true continuation of the Park range proper, as an original Archæan land mass. The Archæan land mass of the Sawatch in Paleozoic times was an oval island about 70 miles long by 20 wide, surrounded by the Paleozoic seas laying down sediments against it.

Through the eastern portion of this area and parallel with its longer axis now runs the valley of the Arkansas River, which in Paleozoic and Mesozoic times did not exist.

The height of these mountain masses above the adjoining valleys may have been far greater then than now, since the sedimentary beds surrounding them and numbering some 10,000 feet in thickness were formed out of material washed from their slopes. They were, however, probably not the only land masses at the time from which this material may have been derived, other land masses may have existed and have been washed away. The great lava flow of the San Juan Mountains may conceal the remnants of a former land mass of great extent.

The ranges were not uplifted by an upthrust from below, but by horizontal, tangential pressure, resulting from contraction of the earth's crust, caused by the cooling of its interior; this is shown by the folded character of the rock masses. The tangential crushing forces were applied in one case at right angles to the lengthwise direction of the mountain mass, in the other in a direction parallel with its axis, *i. e.*, North and South. As the forces of contraction became stronger and the folds were pushed closer together, the folds broke in enormous fractures or faults of many thousands of feet in depth, the forces being exerted on either side towards the central mass. Eruptive rocks poured out in many cases through these fractures and added to the mountain masses, and their ebullitions corresponded to the structural lines of greatest folding and faulting. Along the line of the Parks both earlier and later eruptions are so frequent that their outcrops form a continuous line. From the latter, the Elk Mountains, the head of White River, and the Elkhead Mountains in Wyoming, have apparently been the scenes of most violent and repeated eruptions during both the Mesozoic and Tertiary times.

MOSQUITO RANGE.

The study of this range is necessary to the understanding of the Leadville ore deposits, which occur on its western side. It comprises a length of 19 miles along the crest of the range, and in width includes its foothills bordering the Arkansas Valley on the West, and South Park on the East, a slope in one case of 7½ miles, and in the other of about 9 miles. All of it is about 10,000 feet above the sea level.

The range has a sharp single crest trending North and South. To the West this crest presents abrupt cliffs descending precipitously into great glacial amphitheatres at the head of the streams flowing from the range. Mts. Bross, Cameron and Lincoln constitute an independent uplift. The abrupt slope West of the crest is due to a great fault extending along its foot, by which the western continuation of the sedimentary beds which slope up the eastern spurs and cap the crest, are found at a very much lower elevation on the western spurs. The jagged step-like outline of the western spurs is due to a series of minor parallel faults and folds.

The secondary uplift of Sheep Mountain on the Eastern slope is due to a second great fold and fault.

The elevation of Mount Lincoln is the result of the combination of forces which have uplifted the Mosquito range and those which built up the transverse ridge separating the Middle from the South Park.

The range has been sculptured by glaciers into canons and the Arkansas valley is covered with horizontal terraces representing the distribution of material by waters, on the melting of the glaciers.

In the seas of the Paleozoic and Mesozoic eras which surınded the Sawatch islands, some 10,000 to 12,000 feet of sand-nes, conglomerates, dolomitic limestones and shales were posited. Towards the close of the Cretaceous, eruptions curred by which enormous masses of eruptive rock were ruded through the Archæan floor into the overlying sedi-ntary beds, crossing some of the beds, and then spreading out immense intrusive sheets along the planes of division between different strata.

The intrusive force must have been very great, since compara-ely thin sheets of molten rock were forced continuously for tances of many miles between the sedimentary beds.

That the eruptions were intermittent and continued for a long ne is shown by the great variety of eruptive rocks found. That s eruptive activity preceded the great movement at the close of Cretaceous which uplifted the Mosquito range as well as the ner Rocky Mountain ranges, is proved by the folding and lting of the porphyry eruptions themselves.

In the period intervening between the close of the Cretaceous d the deposition of the Tertiary strata, during which the waters the ocean gradually receded from the Rocky Mountain region, pent-up forces of contraction in the earth's crust, which had ig been accumulating, found expression in dynamic movements the rocky strata, pushing together from the East and the West more recent stratified rocks against the relatively rigid masses the Archæan land, and thus folding and crumpling the beds the vicinity of the shore lines.

The crystalline and already contorted beds of the Archæan ubtless received fresh crumples in this movement.

A minor force also acted North and South, producing gentle eral folds along the foothills at right angles to the trend of the ige. These movements were not paroxysmal or sudden and lent, but protracted for an enormous lapse of time, and pear to be continued in diminished force up to the present day.

MINERAL DEPOSITION.

It was during the period intervening between the intrusion of eruptive rocks and the dynamic movements which uplifted the osquito range, that the original deposition of metallic minerals occurred in the Leadville region, probably in the form of metallic sulphides, though now they are found largely oxidized and in other combinations. They were probably derived from the eruptive rocks themselves, and are therefore of later formation than them. Their having been folded and faulted with them shows that they must have been formed before the great Cretaceous uplift, and therefore that they are older than the Mosquito range itself. The deposits were formed by the action of percolating waters taking up certain ore materials in their passage through neighboring rocks and depositing them in a more concentrated form in their present position. This may have taken place while the sedimentary beds were still covered by the waters of the ocean, and the waters, therefore, may have been derived from it, or the area of the Mosquito range may have already emerged from the ocean and the waters have been estuarine.

STRUCTURAL RESULTS OF THE UPLIFT.

The uplift of the Mosquito range consisted of a series of anticlinal and synclinal folds fractured by faults.

The crest is formed by the great Mosquito fault running North and South along the trend and axis of the range.

The other great fracture is the London mine fault running in a south-easterly direction along the eastern spurs of the range coinciding with a magnificent anticlinal fold seen on Sheep Mountain and in Sacramento Gulch.

On the western or Leadville side the folds, faults and cross-faults are more numerous, breaking the country up into a series of blocks and steps. The movement of these faults has been an upthrow to the East. The greatest movement is towards the center or Leadville region and dies out at either end North and South. In the middle region the aggregate displacement is 8,000 to 10,000 feet.

The crests of the folds and whatever cliffs may have been caused originally by the displacement, have for the most part been planed down by erosion. The erosive forces are best seen in the Arkansas valley which was occupied for over 100 miles by a grand 'mer de glace,' fed by numerous side glaciers from the adjacent ranges. There appears to be evidence in this region of two glacial epochs followed severally by two intervening eras of warmer weather. In the former, moraines were deposited by the ice, in the latter, by the melting of the ice, large fresh water lakes occupied the broad valley of the Arkansas and have left relics of their former presence by extensive horizontal terraces and low table lands. This morainal matter together with the lake beds largely cover the mining area of Leadville and are called locally 'wash', they also at several points afford broad gold placer grounds."

GUNNISON COUNTY

Lies West of Chaffee County, its eastern boundary being partly formed by the crest of the Sawatch range. It contains both a plateau and a mountain region. The former is occupied by horizontal Cretaceous and Tertiary strata.

Except where the Archæan granites are exposed by erosion or eruptive rocks have broken through the sedimentaries, there is not much prospect of the precious metals. Where, however, they do occur, vast bodies of coking, anthracite and semi-bituminous coals of the best quality are on hand for smelting purposes.

The region has heretofore been retarded by the lack of transportation facilities; now that requisite is fully supplied by the Rio Grande and Union Pacific railways.

The geology of the western slope of the Rocky Mountains proper differs somewhat from that of the eastern slope. In the latter region the strata rest usually in their natural consecutive order from Silurian to Tertiary upon the granite, the Silurian lying directly upon it, as upon a shore line.

In the western region and slope, the Cretaceous often lies directly upon the Archæan and the Silurian is not found, implying that a land area existed over this region, raised above the Silurian, Carboniferous, Triassic and Jurassic seas, which were depositing sediment along the eastern flanks, and it was not until the Cretaceous era that this western area, probably by subsidence, was covered by seawater and marine sediments.

The coal-forming period, which on the eastern flanks occurred near the close of the Cretaceous, appears to have occurred, on the western slope, at an earlier date in the same age.

The ore deposits which in the eastern division occur in the Archæan and Paleozoic formations, in the western occur in the Mesozoic rocks as late as the Cretaceous.

The general geological structure of the Elk Mountain region is that of a great "fault fold," an anticlinal fold or arch, running generally with the axis of the range, broken along its crest by a fault. The eastern slope of the fold is gentle, but the western is very steep, and even overturned or inverted.

The Carboniferous, Triassic and Jurassic have escaped erosion in the highest portion of the mountains, while the Cretaceous beds have been eroded away till they lie along the flanks.

In the center of this fold is a mass of eruptive quartz porphyry and diorite, which breaks through the sedimentaries not only in dykes, but also in immense masses forming entire mountains, of which White Rock (diorite), Crested Butte and Gothic Mountains of quartz porphyry are typical. Some of these suggest that they are remnants of laccolites, those reservoirs of molten rock from which the strata have been removed by erosion.

The date of these intrusive masses and eruptions is post Cretaceous, but their characteristics show them to be not of Tertiary type. The intrusion of these enormous masses of molten material, together with the mechanical heat engendered by the violent folding to which the region has been subjected, has produced a widespread metamorphism of the surrounding rocks, including the coal which is metamorphosed into anthracite. Some of the limestones are changed into white marble of superior quality. This metamorphism, combined with other phenomena has made the region peculiarly favorable for metallic veins.

These Elk Mountains are of later origin than the Sawatch range, and probably later than the Mosquito or Park range. They are apparently the youngest mountains in Colorado.

The ore deposits in the Ruby and Irwin districts are of Cretaceous age, as the vein and ore deposits traverse Upper Cretaceous rocks and penetrate the Cretaceous coal horizon.

Ore occurs at a great many localities in the Elk Mountain region and on the flanks of the Sawatch.

The principal mining centers of the Elk Mountain region lie both in Pitkin and in Gunnison Counties, and are as below.

Aspen, on the northeast slope of the Elk Mountains, in the interval between the Elk and Sawatch ranges.

Independence is on the West slope of the Sawatch range.

Ruby, Gothic and others, on the South-West slope of the Elk Mountains.

Pitkin and Tin-Cup, on the South-West slope of the Sawatch.

At Independence, sulphuret ores carrying silver and gold occur.

The "Gold-Cup" mine, near Alpine Pass at Tin-Cup, occurs in the Carboniferous limestone similar to that at Leadville. The ore is argentiferous carbonate of lead and oxide of copper.

At Irwin the "Forest Queen" occurs in a vein associated with a vertical porphyry dyke traversing the Cretaceous sandstones. The ore is ruby silver, arsenical pyrites and sulphurets of silver, occurring in small crevices and fissures in the decomposed porphyry. The gangue is an indistinctly banded quartz. Faults occur in the mine.

On Copper Creek, near Gothic, a series of nearly vertical fissure veins traverse the eruptive diorite rocks. These veins are mineral-bearing, and at the Sylvanite mine have produced a great deal of very rich ore. Among it are very large masses of sulphurets of silver and extraordinary specimens of native silver, in curly bunches resembling bunches of tow, in considerable quantities. Some of these silver curls are oxidized into a bright golden color.

PITKIN COUNTY.

THE ASPEN MINING REGION.

The ore deposits of Aspen occur in the same geological horizon as those of Leadville, viz.: The lower Carboniferous, shown by the fact that the limestone enclosing the ore contains fossils similar to those found in the ore-bearing limestone of Leadville, as also by its position relative to the Cambrian quartzite and Archæan granite below, and the Carbonaceous shales and Weber grits of the Middle Carboniferous above it.

Aspen Mountain is on the risen side of a great fault which is clearly seen on Castle Creek on its Southern side, by which the

Mesozoic red beds, and other groups, have fallen several thousand feet from their proper position above the Paleozoic series, which cap the summit and sides of the mountain in which the mines are principally located.

This faulting was due to the elevation of the Elk Mountains crushing the intervening sedimentary strata between them and the Sawatch range, into a series of folds which, when they had reached their greatest tension, broke into a series of faults. Besides the one great fault there were several minor faults attending this movement, which are found in various parts of the mountain and adjacent region. Some of these faults are more recent than the ore deposits, as they fault them slightly. Whatever motion is visible in the mines, such as slickensides and smoothed walls is to be attributed to these later movements rather than to the production of any fissure subsequently filled by the ore deposits. The ore appears to occur as a replacement of limestone, the lower portion of which is dolomitic in character, while the upper portion is true limestone. The ore replaces both forms of the limestone and penetrates its mass through various jointing planes spreading out also at intervals between the planes of stratification in a more or less irregular way. The principal line of concentration appears to be at the point where the limestone becomes dolomitized.

Overlying the limestone, but separated from it by a thick bed of black argillaceous shale is an enormous mass of eruptive diorite, from which it seems probable that the ores were derived through the medium of percolating surface waters in a somewhat similar way to that at Leadville.

The ores are fine-grained galena, rich in silver. A good deal of silver sulphurets, polybasite, and decomposition products of these.

As we published the results of our examination of the district in last year's report, we will not repeat the details here, but as the region has so rapidly developed in importance since then, an importance which is daily increasing, the results of a subsequent examination by Mr. S. F. Emmons of the Geological Survey, read before the Scientific Society of Denver, will be of interest, and we give an epitome of it here, with the greater pleasure as

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while confirming many of the published views of the writer of this treatise and correcting others, it adds also a great deal of fresh material of great value to those interested in the Aspen mines.

ABSTRACT OF PAPER ON THE ASPEN MINING REGION, BY S. F. EMMONS.

"The Aspen mining region is related to that of Leadville. Each is on the shore line of the old Archæan island of the Sawatch, one on the East, the other on the West, and about opposite one another, (though about fifty miles apart.)

The ore deposits occur in the same general horizon as at Leadville, viz., the Lower Carboniferous limestone.

Both are regions of intense dynamic disturbances, which have been accompanied by immense intrusions of igneous rock through the sedimentary strata.

The process of ore deposition in either region has been an actual replacement of the country rock by vein material, and where open cavities occur they are found to be of later formation than the original deposition of ore.

At Aspen the ore is not found in actual contact with the eruptive bodies, as is generally the case at Leadville, and the country rock, instead of being entirely dolomite, is only partially so, and whereas at Leadville there is reason to assume that it was originally deposited as a dolomite, at Aspen there is some reason for thinking that the dolomitization may have been in part, at any rate, a secondary process, entirely subsequent to the deposition of the limestone."

"The mines of Aspen are situated in Paleozoic strata reclining upon the slope of a narrow ridged mountain forming a granite spur *en échelon* with the Sawatch range.

The strip of country in the vicinity of Aspen constitutes the dividing line between the two distinct uplifts of the Sawatch range on the East and of the Elk Mountains on the West, and has been affected successively by the dynamic movements accompanying each upheaval.

The Sawatch upheaval was a gradual elevation of this mountain mass, resulting from a gradual subsidence of the adjoining sea bottoms, which caused the sedimentary beds deposited in those sea bottoms to slope up at varying angles all along the ancient shore line toward the central mass of the Archæan island.

The Elk Mountain range, which extends to the West and South of this region, was upheaved later than the Sawatch, with greater violence and eruptive energy, and the upheaval was accompanied by enormous intrusions of eruptive rock which were forced into the sedimentary strata already shattered by the forces of upheaval, in great 'laccolites,' or solid masses, and spread out through them in every direction in the form of dykes and intrusive sheets. The surface exposures of these igneous bodies cover areas of twenty-five to thirty square miles, and their extension below the surface is doubtless very much greater.

The intrusion of such enormous masses of foreign matter must not only have greatly disturbed the beds within the region of upheaval, but also have so expanded the volume of the earth's crust in this area as to cause a severe lateral pressure in the adjoining region. That adjoining region was Aspen and its neighborhood.

It would be just in the strip of sedimentary beds along the Aspen Mountain ridge, which is backed by a projecting point of the unyielding Sawatch Archæan that this compression would be most severely felt, the Sawatch granite mass acting as a point of resistance against the intense lateral compression caused by the younger Elk Mountain uplift.

The sedimentary beds resting against the Archæan correspond generally, with slight differences, to those in the South Park and Leadville region in a similar position.

STRATIGRAPHY OF ASPEN.

The latter were deposited in a partially enclosed bay, now constituting the South Park basin, the former on the West side of the Archæan island in a wider and deeper sea, and on this western slope the beds are generally much thicker than those of corresponding geological horizons on the East.

1. The horizons represented are the Upper Cambrian quartzites, 200 feet, resting on the Archæan granite.

2. Silurian silicious limestones and quartzites, 340 feet.

3. Darker limestones, rusty brown and dolomitic at base, blue
pact and pure on top, 240 feet. (These are Lower Carbon-
ous.)

4. Carboniferous clays and shales and thin bedded limestones,
feet. These belong to the Weber grits (Middle Carbon-
ous).

5. A series of variegated green and red sandstones, clays
shales, some limestones and red sandstones of the Upper
boniferous.

6. Heavy bedded red sandstones (Triassic).

Above these again are several thousand feet of Cretaceous
ta, up to the base of the Laramie coal beds. (The Creta-
us, however, and the Jurassic do not rest immediately in any
upon the granite.)

Diorite. On Aspen Mountain is a bed of white porphyry
rite) in the black shales, 60 to 100 feet above the top of the
limestone. It is 260 feet thick on the slope back of town,
thickens considerably to the South, and is traceable to Ash-
t." [It appears to extend also across the valley of Roaring
k to Smuggler Mountain. Small intrusive sheets also occur
he lower quartzites near the point of Aspen Mountain and on
East face of Richmond Hill.]

"As affected by the Sawatch upheaval, these beds wrap around
Archæan mass resting against or dipping away from it at
ying angles.

The quartzites and limestones cross the valley of Roaring
k from Smuggler Mountain to Aspen Mountain, striking
th-East and South-West, dipping North-West. The angle
lip is about 45°, varying from a minimum of 30° to a maxi-
n of 60° in 'flats' and 'steeps.'

At the upper end of Spar Ridge, blue limestones change in
ke from North-East to North, bending to the South till they
ch Ashcroft, the westward dip shallowing nearly to a horizontal
he head of Spar Gulch and steepening again to 45° near
ncroft.

In the hills forming the East bank of Roaring Fork valley,
n Smuggler Mountain Northwestward is a continuous con-
nable series of beds from Cambrian to Cretaceous dipping

Northwest. Were this region affected by the Sawatch upheaval alone, we should expect to find this same series sweeping continuously around and resting comformably upon the flanks of the lower Paleozoic strata which form the crest of the ridge from Aspen to Ashcroft. Instead of this, on the steep West slope of Aspen Mountain, towards Castle Creek, we find, now the blue limestone, now the Cambrian quartzites and again the Archæan granite, abutting against the Triassic beds, and going northward along the East slope of the Mountain back of Aspen City. After passing geologically upwards through blue limestone, black shales, porphyry and black shales again, we find the series repeated at the point of the ridge from granite up to blue limestone again, the latter beds lying in great slabs against its Northern ends, striking East and dipping about 60° to the North.

This is the result not of mere folding but the extreme compression resulting in faulting.

There is not only one great fault, but several smaller parallel ones. This compression proceeded from the upheaval of the Elk Mountains crowding the sedimentary beds against the unyielding Sawatch Archæan mass, so that along its edge they have been broken across and shoved up past each other.

CASTLE CREEK FAULT.

The line of the principal fault is shown by its movement bringing the red sandstones in juxtaposition to the limestones, quartzites and Archæan rocks on the East. The minor faults are more obscured by debris. The main fault is visible around the point of Aspen Mountain, where Castle Creek cuts into its northern foot. Vertical red sandstones striking North and South appear parallel to the fault plane. These adjoin the steeply upturned quartzites which strike East and West across the northern end of the ridge. The fault runs for several miles southward along the foot of the hill, parallel with the bed of the creek, gradually rising higher on the slope. On the West side of the fault the red beds stand either vertical or dipping slightly eastward.

In the hills on the West side of Castle Creek the same beds are nearly horizontal, or dip 10° to 20° to the North down the creek. The beds exposed are successively lower as we ascend the creek. At Queens Gulch there is a decided dip eastward of the red beds 15° from a vertical. To connect the vertical beds with the horizontal on the opposit side of the creek would involve an S shaped synclinal. Such a fold is evidence of intense compression accompanying the faulting, sufficient to double together these heavy sandstones as closely as one folds sheets of paper. Queens Butte about two miles below Aspen is a good example of this overturned S fold, the Jurassic beds lying on top of the overturned Cretaceous.

This butte is on the same line of fault and marks its continuation in that direction.

In Ophir Gulch the line of the fault is well marked by an outcrop of granite in the bed of the gulch adjoining the sharply upturned red sandstones. A tunnel has been run in on it, and the fault plane of the granite wall dips 45° to the East.

The fault there is a reversed fault, because the upward movement was in the hanging wall contrary to the usual law of faults by which the foot wall rises. The plane of the Castle Creek fault has an eastward dip, instead of a westward one, implied also by the fact of the beds immediately adjoining the fault on the West often dipping East also.

Beds West of the faults were more plastic than the older ones now adjoining it on the East. The former not being fractured, the latter being broken by many minor faults parallel to the main fault with no evidence of such closely compressed folding as exists in the former.

In Queens Gulch white quartzite is the first outcrop East of the fault, then over-lying brown limestone, a gap, and then quartzite dipping 45° West, granite below them in tunnel. One thousand feet above this are the Queens Cliff outcrops of blue limestone and brown limestone forming the southern point of Aspen Mountain.

On the ridge running West from Queens Cliff between Ophir and Queens Gulches are three minor faults West of the main fault. One mine shaft here had a limestone East wall and a red sandstone West wall. Another shaft in a fissure, had porphyry on the East and limestone on the West. Another had limestone

one side and granite the other. The latter had crossed the fault line and was drifting hopelessly into the Archæan mass.

On the summit of Queens Gulch at Queens Cliff is an exposure of several hundred feet of blue and brown limestone dipping 15° West. On the ridge, East of this, across the head of Spar Gulch on Ajax Hill the same series is repeated, separated by a slight fault on the line of Spar Gulch. Following down the East slope of this hill we cross successively the lower limestones and Cambrian quarzites striking North and South dipping gently West, and found resting upon the Archæan at the base of the first steep slope of the ridge, 500 feet below the summit.

NORTHERN PORTION OF ASPEN MOUNTAIN.

For some distance North of Queens Cliff limestone is the cap rock of the ridge, the overlying porphyry having been eroded off. On the round-topped hill at the head of Ophir Gulch on whose East face is the "Campbird" Mine, several hundred feet of porphyry overly the limestone.

Its sudden appearance is accounted for by a fault crossing its Southern end running West of North with upthrow on the South. Northward from here as far as the head of Keno Gulch porphyry forms the whole upper portion of the ridge. Below it along the West wall of Spar Gulch the limestones and their ore-bearing zone are traced by occasional out-crops, and by the workings of many mines.

The line between porphyry and limestone descends to the North till the change of strike from North to Northeast comes in, where the bend causes a steepening of the strata.

The blue limestone of Spar ridge runs diagonally across the course of Spar Gulch closing it into a very narrow ravine in its lower portion, and finally crossing it at the bottom, passes over the point of the main ridge to the East of it, to disappear beneath the valley of Roaring Fork.

The overlying porphyry also bends around to the Northeast conformably and forms the ridge bounding Valejo Gulch on the North, on the sloping crest of which several shafts have been sunk.

To the North, beneath the surface, on the East slopes of Aspen untain several hundred feet of dark limestones and Carbona-us shales rest conformably on the porphyry sheet though near surface they have been eroded off.

The beds follow normally the outline of the Archæan, not ken by any serious faults.

Minor faults following the direction of the Castle Creek fault be found like that which runs across Spar ridge above the rant cliff, extending across the Bonny-Bell ground on the ith and the Aspen on the North.

From the head of Keno Gulch North, the ridge of Aspen untain is set off ***en échelon*** to the West of the main ridge, as whole body of the mountain is set off from the main ridge at eens Cliff. The highest and most Southern point of this ridge rlooking the head of Keno Gulch, ('Acquisition Hill,') is arated from the main ridge by a V-shaped depression running th and South.

Brown limestone, granite and white quartzite appear, the ner at the Southern end and running along the Eastern face in ortherly direction. Granite adjoins it on the West and quartzite rests on granite on the North and West.

Faulting has brought the limestone and granite into juxtapo-on. The fault plane is cut in the Acquisition mine, whose nel passes from the brown limestone into granite at 300 feet lowing the ridge North, beds of limestone and quartzite appear king North and South, with steep dips. About half way to North point granite comes in, forming the crest of the ridge ar as where the successive great slab-like masses of quartzite limestone rest against it, and dipping steeply North, form the reme point of the mountain.

On the South and East of this mass of granite, the beds are ken by a series of minor faults, running North and South. ar the Pioneer, in some tunnels, vertical faults and slip planes ning North and South occur, the striations indicating an vard and downward movement at an angle of 60° to the hori-, towards the North, or in a reversed direction downward towards the South. The beds North of the granite have an st and West strike, but tend to wrap around the granite body, n the East they curve in strike to the southward.

The structure of this ridge is as follows: By the movement of Castle Creek fault this body of granite and the strata resting on its North side were dragged bodily upwards from their normal position on the downward dip of the beds out-cropping in Spar Gulch, and with a relatively greater movement of displacement than the rest of the region, since they must have been lower down originally.

The upward movement was relatively greater immediately adjoining the fault than at some little distance to the East, and thus the West end of these uplifted beds was carried further upward and northward than the East end. Their strike was shifted from North-East to East and a little South of East.

In the intermediate region to the South-East between the granite beds and the normally dipping beds of Vallejo Gulch, which is farther away from the fault plane, the beds were dragged up on the flanks of this upward moving granite body, not in a single mass like the strata to the North, but holding back as it were, sloping up against it at steep angles, and slipping back along minor fault planes.

As the limestone on the steep side by the Pioneer mine dip East, an anticlinal fold over the granite, and a synclinal fold or basin between it and Vallejo Gulch has been assumed to exist. There may have been an abortive attempt to form such folds, but the space was too limited for their free development and they were fractured before the folding was completed. There are no continuous unbroken curves representing folds except perhaps in the re-entering angle of the hill formed by the upper part of Pioneer Gulch.

The New York tunnel, 1,000 feet above the town, runs 1,100 feet into the hill in a direction South 20° West. It crosses the strata at right angles.

These have a North-Westerly instead of a North-Easterly strike. It passes through 100 feet wash, 585 feet conformable limestone, shales and included porphyry, before reaching the top of the blue limestone.

It is possible, though improbable, that a horizontal drift running South-East along a given bed, such as the blue limestone, would make a continuous curve to the North-East unbroken by

a fault before reaching the out-crop of the Spar Gulch, and so prove the existence of a synclinal basin under the northern portion of the porphyry. Of continuous folds North of this, there is no possibility, and while the Spar Ridge limestone stretches across Roaring Fork Valley to Smuggler Hill, and ore bodies may be found beneath the valley, the same continuity cannot be expected in the limestone beds of the northern point of the mountain. The beds in a corresponding position to them on the East side of the valley belong to a higher geological horizon, hence somewhere in the valley between they must be cut off by faults, probably nearer to Aspen Mountain than to the other side of the valley.

ORE-BEARING HORIZON SUPPOSED TO BE AT CONTACT OF BLUE LIMESTONE AND UNDERLYING DOLOMITE OR BROWN LIMESTONE.

The blue limestone is compact, homogeneous and pure carbonate of lime, when crystalline its crystals are larger than those of the dolomite. The brown limestone, when unaltered, is of a dark blue gray, finely crystalline, finely granulated, and traversed in every direction by a net work of minute veins containing iron salts which when oxidized color the surface a rusty brown.

The oxidization along these minute veins makes it break easily into dice-shaped fragments giving the rock a 'crackly' structure hence its name of 'short lime.' The rock has not been crushed or brecciated, it is a true dolomite.

The thickness of the blue limestone is from 120 to 150 feet.

On the cliff on Spar ridge above the Durant Mine, six lenticular seams of dolomite are included in the blue limestone, wheathering more rapidly than the blue, they produce indentations in the cliff.

On Smuggler Mountain the presence of the blue limestone is not clear. It is doubtful if the 'contact' is one and the same geological horizon throughout the region.

From a few fossils and lithological structure, both blue and brown limestone belong to the same horizon, the Lower Carboniferous. The ore was not deposited in a fissure formed by the movement of the blue limestone over the brown dolomite, if it had been, striated surfaces and crushed material would be found along the plane of movement. Such slickensides and structures as are found in portions of the Spar and other mines are due to movements after the ore was deposited."

Ore Distribution.—The outlines of the ore bodies cannot be detected by the eye owing to the gradual transition from ore to country rock..

The ore is not confined to the brown dolomite below the contact but several ore bodies extend 20 or 30 feet above this contact into the blue limestone and in some cases follow the lines of cross-fracture entirely across the blue limestone.

This ore is not confined, either, to a definite plane or contact between two dissimilar beds of limestone and dolomite from which its solutions have eaten into the underlying dolomite, for in the first place there is not one single contact, but many, and if this so-called "contact" constitutes an essential condition of ore deposition, there is no reason why it should be confined to the one and not found in the others where the rocks have the same composition. Again, ore-bearing solutions are not likely to eat upwards for any great distance from the contact plane if they entered the beds along this plane.

This contact plane is well defined on Spar ridge and continues down with the dip in the underground workings, but ore bodies occur both above and below it.

The rock thus mineralized is dolomite in most cases, but is none the less above the true bedding plane called the contact.

In other parts there has been fracturing across the beds as shown by a vertical breccia of limestone fragments with a cement of iron oxide and manganese.

Over the ore bodies are lines of open cavities following the lines of cross-fracture through which the ore solutions passed which deposited the ore bodies. These caves are now being hollowed out by water descending from the surface dissolving the limestone in the roof and flowing off along the floor depositing a mud of silica alumina, lime, magnesia and iron oxide.

Hence this contact is not necessarily the only ore channel of the district, and other channels may be sought for.

Portions of the ore bodies have been formed by solutions percolating through cross-fractures and spreading out between the parallel bedding planes.

This would happen if these solutions derived their metals m the overlying porphyry, for it is separated from the limestone argillaceous shales which would be impervious unless fractured oss the bedding. The analysis of the lime mud at bottom of cave shows by its preponderance of alkalies, which do not ist in the composition of either brown or blue limestone, that waters dissolving it came from the porphyry. The waters ought both alkalies and silica from the porphyry, and probably iron and baryta.

DOLOMITIZATION.

This is a secondary process upon the blue limestone by magsian waters, which is proved by irregular tongues of dolomite tending up into and across the blue limestone. The lenticular dies in the Durant cliff point to the same fact. The crackly ucture of the brown lime results from the replacement of a lecule of lime by a molecule of magnesia, involving also a ntraction in volume of the rock itself, which would cause it to parate in angular fragments, the intersections filled by material re soluble than the rock itself.

The magnesian waters may have been connected with those ich brought in the vein materials.

In the ore bodies the partially mineralized rock on the bors of the ore is changed to dolomite, hence dolomitization either ceded or accompanied ore deposition.

Mr. Emmons suggests as *probabilities* only, that the porphyry rusion preceded the faulting.

That the ore deposit followed the intrusion of porphyry and o the principal faulting movements.

That small movements have taken place in recent times both the strata and contained ore bodies since the oxidation of the ter. That at the time of the great faulting, the beds may not ve attained entirely the present position.

THE SAN JUAN REGION.

This region, which embraces San Juan, Hinsdale, Ouray, La ata, and part of Rio Grande and Conejos Counties, takes its me from the San Juan Mountains, a lofty, irregular mountain mass of a North-West trend, composed almost entirely of prodigious flows of lava, emanating in all probability from a series of dykes concealed underneath the flows. These horizontal flows have buried under their mass the primitive granite which is occasionally to be found peeping out from underneath it at the bottom of the profound canons, from whose depths you can look up at a vertical section of from 2,000 to 3,000 feet of lava lying layer upon layer of different colors. Some of these eruptive rocks consist of enormous thicknesses of volcanic "breccia" or conglomerate, which have a leadish gray appearance at a distance, but on nearer inspection the fragments composing them partake of an olive green or lilac color. There appear to be two sets of these eruptive rocks, one of older date than the other. The breccias belonging to a porphyritic or dioritic type are locally penetrated by dykes or covered by flows of newer eruptions, such as rhyolites, andesites and basalts. While some are Tertiary eruptives, others are of older date, and it is in these latter, particularly in the breccias, that the mineral veins more especially occur.

In certain portions of this region, besides the granite, sedimentary rocks of Carboniferous age, such as limestones and quartzites, and red sandstones of Triassic age, appear from under the prodigious lava covering.

They are generally more or less uplifted, while the lavas rest upon them horizontally. It is apparent then, that the eruptions occurred after the Triassic, and also after the underlying strata had been upliftod into something like mountain forms.

At the head of Uncompahgre River, near Ouray, Paleozoic limestones and quartzites, and Triassic red sandstones, rest on the granite, and dip to the North-West under the Cretaceous formations covering the Counties of Ouray and La Plata, which belong to the Colorado plateau region. In the Southern part of San Juan County the same feature is observed.

Ore Deposits.—Probably few regions in the world are traversed by so many and such large veins. Immense vertical veins of a hard bluish quartz traverse the eruptive rocks. Their outcrops project like walls from the surface, or run down either side of the profound canons for several thousands of feet, and though they penetrate both older and younger eruptive sheets, the ore bodies are most productive in the older eruptions, especially the brecciated rocks. Veins also occur in the underlying granite and gneiss.

At Rico deposits occur between the bedding planes of Carboniferous limestones at contact with sheets of intrusive igneous rocks. The deposits are mainly argentiferous. Both gold and silver, however, occur in the lodes. Rich gold placer deposits are found near San Miguel.

The minerals are principally argentiferous galena, gray copper and bismuthinite, with ruby silver, native silver and zinc-blende. Molybdenite is not uncommon. Barite sometimes forms the gangue in place of the hard chalcedonic quartz. The veins often have a banded structure, and sometimes a brecciated one. In many cases one or both walls are not clearly defined, and a portion of the vein material is decomposed country rock.

There are two sets of veins traversing the region, one having a North-West by South-East, the other a North-East by South-West direction, thus cutting one another diagonally. The North-West is the commoner in direction.

CUSTER COUNTY.

"Comprises the Wet Mountain valley lying between the Wet Mountains or Greenhorn range on the East and the North end of the Sangre de Christo range on the West.

The Greenhorn range is a continuation of the front or Colorado range of Archæan granite with Mesozoic formations resting against its eastern base.

The lofty Sangre de Christo range is a continuation of the Mosquito or Park range and its geological structure, but little known, is probably similar, viz., Paleozoic quartzites and limestones, resting upon granite and traversed by dykes, of porphyries and other eruptive rocks.

The principal mines are near Silver Cliff and Rosita, an area of ten miles by six. The underlying Archæan is broken through and covered by eruptive rocks consisting of diabase, a heavy dark rock, andesite, and rhyolite, which outcrop at Silver Cliff and

Rosita. Silver Cliff city is on the open plain near a 'mesa' ridge on whose cliff face the silver deposits are developed in the 'Racine Boy' mine. The rock of this cliff is a light pinkish rhyolite, showing the laminated fluidal structure peculiar to this variety of lava. A black glassy variety of rhyolite also occurs.

Outcrops of granite are found on the plains between Silver Cliff and Rosita, implying that the rhyolite rests on under-lying Archæan. Two miles North in the Blue Mountains, is the 'Bull Domingo' mine.

The ore deposits are peculiar. The 'Bassick' and 'Bull Domingo" situated near the northern limits of the eruptive rocks, are among the most remarkable mines.

The peculiar feature of both these mines is that the ore is found in large bodies without any definite boundary, forming a coating on irregularly rounded fragments of the adjacent country rock. The popular theory that the mines are old craters or solfataric openings in which the fragments of rock have been tossed about rounded by attrition and coated by metallic vapors and solutions, does not seem to be borne out by careful examination of the neighborhood, according to Emmons.

The country rock of the 'Bull Domingo' is a hornblendic gneiss of Archæan age.

The ore, principally agentiferous galena, forms a regular semi-crystalline coating from one-eighth to one-fourth inch thick around boulders and pebbles of rock, and fills the interstices between them. These pebbles are not in direct contact one with the other, but are separated by the metallic coating belonging to each individual pebble.

The galena is covered by a second botryoidal coating of a silicious nature. The deposit is from forty to sixty feet wide and strikes in a northwesterly direction. The country rock of the 'Bassick' appears to be a 'Breccia' of volcanic pebbles and the ore to be a replacement of the 'Matrix.'

The Bassick deposit is an irregular oval opening from twenty to 100 feet in width, occurring vertically to the present depth of development of 800 feet, an oval well, as it were, in the rocks.

The fragments of rock filling this opening, vary in size from two feet to the smallest dimensions. They are rarely in contact with one another while the metallic coatings surrounding them touch one another. The size of the fragments as well as the quantity of ore present decreases from the center outward without any definite limit having been determined.

In the metallic coating there is a series of concentric layers, the innermost and thinnest consists of sulphide of lead, antimony and zinc, assaying sixty ounces silver and one to three ounces gold to ton.

A second coating lighter in color contains more lead, silver and gold.

The third shell is zinc-blende, carrying sixty to 100 ounces silver, fifteen to fifty ounces gold, with a good deal of iron and some copper.

The fourth shell is of copper pyrites, carrying fifty to 100 ounces gold and silver. These layers are not always constant or complete, they have a crystalline structure; the remaining intersections between the pebbles are filled with Kaolin.

Small fragments of charcoal are found in cavities between the boulders toward the outer edges of the ore body and near the water level. These are sometimes partially mineralized and at others are perfectly unaltered and retain the woody structure.

The greatest depth at which they have been found is 765 feet from the surface.

Silicate of zinc, gray copper, free gold and tellurides of silver and gold are also found in small quantities in the mine.

The 'Racine Boy,' near Silver Cliff, is an irregular impregnation of the country rock. Chloride of silver occurs in it, the ore is low grade but occurs in great quantities.

From the Gem Mine a rich nickel ore has been obtained.

HUERFANO COUNTY.

Ore occurs in the Spanish Peaks. The ore is galena, pyrite and gray copper, occuring in a gangue of quartz in the joints of the porphyry. In the 'Monarch' mine the veins are in the porphyry which composes these majestic eruptive Mountains whose history is that of a vast number of dykes emanating from a grand center of eruption which constitutes the core of these peaks."

CONCLUDING REMARKS.

These examples we have selected from the principal mining districts of Colorado to illustrate the principles in the preceding part of this work, afford us good types of the geological formations in which the ores are principally found as well as their typical mode of occurrence, viz: The Archæan granitic series with its fissure veins, the typical volcanic region of San Juan, in which fissure veins also occur in enormous masses of eruptive rock only, and the sedimentary series, such as limestones and quartzites, penetrated by intrusive eruptive rocks in which the ore occurs in bedded deposits or pockets.

There has been and may still exist a prevailing prejudice in favor of fissure veins on account of their supposed steady reliability to great depths, and against bedded deposits or "blanket veins" as they are sometimes called especially when they occur in limestone, on account of their supposed uncertain continuity for any great distance.

The developments of Leadville and Aspen have shown this prejudice to be unfounded, at least in Colorado, and haveal most overturned the scale in favor of bedded deposits in limestone, since the riches derived through a few years from these formations have far exceeded all that has been obtained from the fissure veins of Colorado in granitic rocks in the whole course of Colorado history. It is true that sometimes ore deposits occur in a series of almost isolated and disconnected "chambers" or "pockets" and that much labor and expense is spent in hunting for a second pocket after the first has been exhausted, but they are the exceptions in Colorado rather than the rule, and quite the same thing not unfrequently occurs in the more popular fissure veins. A 'pinch' or a practically barren interval of an unknown length may occur between one productive part of a fissure vein and another.

In the Leadville ore deposits the ore not only occurs as a broad sheet or blanket between the overlying porphyry and the limestone, but also descends at intervals in large and irregular pockets into the mass of the limestone itself. The same occurs at Aspen also. There has been far less difficulty in both these camps of following down these blanket deposits with occasional pinches and widenings, and pockets in comparatively soft limestone gangue than in pursuing the steep downward course of a fissure vein in granite or eruptive rock with its hard gangue of quartz.

As to the continuity and reliable lasting powers of these so-called bedded blanket deposits so far as we can judge from those at Leadville which have been worked now for upwards of ten years, there seems nothing against there lasting for centuries, or to the limit of depth to which mining operations can be carried.

The ores in limestone, from their oxidized character, are easier treated at the smelter as a rule than those found in fissure veins.

As for degree of richnesss, we have but to look at the late extraordinary rich developments at Aspen to show that bedded deposits in limestone can equal and far surpass in richness and quantity the average fissure veins in granite rocks, so that the answer of an experienced mining man to the question whether he would rather have a fissure vein in granite or a bedded deposit in limestone, had some reason in it when he replied, "Give me a limestone deposit, every time." We do not underrate fissure veins, but we think they have been overrated to the disparagement of other forms of mineral occurrence quite their equals, and often their superiors.

With regard to fissure veins, from what we have said it will appear that in Colorado, at least, we have very few that will answer to the orthodox type, as represented in some of our text books, viz., a once wide open fissure with well defined walls that has been gradually filled by mineral solutions ascending from heated depths below.

We do not think the original fissures were wide, or at least so wide as some of the fissure veins now are, such as fifty to one hundred feet in width, but that they were rather narrow cracks, such as produced by faulting and jointing, or lines of weakness between stratification planes which were worked upon by solutions oozing from the adjacent country rock, robbing that rock of the metal elements minutely contained in its constituent minerals, and redepositing them in various combinations in a more available and crystalline form in the fissure or line of weakness. The great width of some of our veins we attribute rather to the altering, corroding power of these solutions on the country rock than to the original width of the fissure.

The fissures or fault lines of some of the profound faults in our mountains do not present a wide open fissure abyss, but narrow cracks sometimes almost welded together again by heat and pressure; the adjacent rock in the immediate proximity of the fault is also much broken, cracked and fractured. Upon just such a line of weakness and of broken rock, mineral solutions working, would dissolve, alter and replace portions of the broken rock constituting a wide vein whilst other portions would be left unsubstituted and constitute a breccia, or the solutions working around large fragments would present us with the phenomena of those horses and split veins we see so well represented in the fissure veins of San Juan and elsewhere.

The medium for filling these fissures with veinstone and metal was in all cases water, probably heated and charged with various alkalies and salts.

The favorite circumstances for rich ore occurrence in Colorado are in what are called "contacts." The ore body, lying between two rocks of a different character, usually between an eruptive porphyry and some other sedimentary metamorphic or non-eruptive rock. These "contacts" may occur both in connection with fissure veins and bedded deposits in both the granitic and limestone districts.

It is important then for prospectors to keep a look-out, not so much for one particular kind of rock, but the juncture of two different rocks, one eruptive and the other not, and prospect at the line of juncture.

The eruptive rock is not always necessary in immediate contact with the ore or ore-bearing rock, but may be sufficiently near to influence rocks in its vicinity with mineral solutions emanating from it. Not a *single* circumstance but a *combination* of circumstances which we have detailed in this work constitute an ore-bearing area.

Sometimes a miner may mistake the plane of a fault for a true contact; he may have been perhaps for sometime following a dipping or blanket vein and encounter suddenly an abrupt all of granite or possibly porphyry, the result of a fault, which far from being a desired contact is practically the terminus his mining operations. Cases have occurred where the miner as still pursued the even tenor of his way and gone on nnelling in the granite with, of course, no results.

We cannot too strongly emphasize what we have said in the ody of this treatise relative to the popular, mischievous fallacy supposing that richness must almost necessarily increase with epth, and that though evidences seem poor for moderate depth elow the surface, yet "if we only go deep enough we are pretty ure to strike it rich."

There is no scientific reason one way or the other for this, and xperience is rather against richness with great depth. Nearly l our gold veins are richer and more valuable near the surface, nd in the oxidized portion than with depth. Oxidized ores all classes within moderate depth from the surface are, as rule, richer and easier treated than those found at great depth. onsideration of this fact would prevent much money being sked or wasted in expensive, need less cross-cut tunnels in dead ck, at some low point, in hopes of tapping the vein at great epth. It should also prevent parties unacquainted with mining expecting too much with depth from lodes that have not roved very profitable near the surface. Notable and important xceptions we admit often occur to this general rule.

In examining a mining property with a view to forming estiates of its value, a thorough system of assaying should be ursued in various parts of the ore body, especially in the more verage and poorer parts of the vein. Rich specimens should e studiously avoided. Assays from such would give a most audulent report of the mine. There is a certain district in rkansas from which glowing reports have been made, backed p by these specimen assays, whilst the region is utterly valueless. o show a specimen from a mine coated with native gold or lver is a common device of the unscrupulous man who has a hole in the ground" to sell to some "tenderfoot" who is struck ith mining fever and is too ready to believe what "he sees with is own eyes" By and by "the proof of the pie will come in e eating thereof."

Appendix.

THEORIES OF VEIN FORMATION AND ORE DEPOSITS.

Dr. J. S. Newberry, of Columbia School of Mines, groups mineral veins in three categories: 1. Gash veins. 2. Segregated veins. 3. Fissure veins.

Gash Veins.—"Ore deposits confined to a single bed or formation of *limestone*, of which the joints, and sometimes planes of bedding, enlarged by the solvent power of atmospheric water, carrying carbonic acid, and forming crevices, galleries, or caves, are lined or filled with ore leached from the surrounding rock; e. g., the lead deposits of the Upper Mississippi and Missouri.

Segregated Veins.—"Sheets of quartzose matter, chiefly lenticular, and conforming to the bedding of the enclosing rocks, but sometimes filling irregular fractures across such bedding; found only in metamorphic rocks, limited in extent laterally and vertically, and consisting of material indigenous to the strata in which they occur, separated in the process of metamorphism; e. g., quartz ledges carrying gold, copper, iron pyrites, etc., in the Alleghanies, New England, Canada, etc.

Fissure Veins.—"Sheets of metalliferous matter filling fissures, caused by subterranean force, usually in the planes of faults, and formed by the deposit of various minerals *brought from a lower level* by water, which, under pressure, and at a *high temperature*, having great solvent power, had become loaded with matters leached from different rocks, and deposited them in the channels of escape as the pressure and temperature were reduced.

Bedded Veins.—"Are zones or layers of a sedimentary rock, to the bedding of which they are conformable; impregnated with ore *derived from a foreign source*, and formed long subsequent to the deposition of the containing formation." Several of the mines of Utah are cited, which are all zones in quarztite, which have been traversed by mineral solutions that have, by substitution, converted such layers into ore deposits of considerable magnitude and value.

"The ore contained in these bedded veins exhibits some variety of composition, but where unaffected by atmospheric action, consists of argentiferous galena, iron pyrites carrying gold, or the sulphides of zinc and copper, containing silver or gold or both. The lead carbonate and galena are often stained with copper carbonates. In the 'Green-eyed Monster' mine of Utah the ore, thoroughly oxidized as far as penetrated, forms a sheet from twenty to forty feet thick, consisting of rusty, sandy or talcose soft material, carrying from twenty to thirty dollars to the ton in gold and silver.

"The quartzites are of Silurian age, but were impregnated by metalliferous solutions much later, probably in the Tertiary, and after the period of disturbance in which they were elevated and metamorphosed. This is proven by the fact that in places where the rock has been shattered, strings of ore run off from the main body, cross the bedding and fill interstices between the fragments, forming a coarse 'stock work.'

"Bedded veins may be distinguished from fissure veins by the absence of all traces of a fissure, the want of a banded structure, slickensides, gouge, etc.; from 'gash veins' and the 'floors of ore' which accompany them, as well as from segregated veins, they are distinguished by the nature of the enclosing rock and the *foreign origin* of the ore.

Sometimes the plane of juncture between the two contiguous sheets of rock has been the channel through which has flowed a a metalliferous solution, and the zone where the ore has replaced by substitution portions of one or both strata. These are often called *blanket veins* in the West, but belong rather to the class of 'contact deposits.'

"Where such sheets of ore occupy, by preference, the planes of contact between adjacent strata, but sometimes desert such planes and show slickensided walls and banded structure, like the great veins of Bingham, Utah, these should be classed as true fissure veins."

THEORIES OF ORE DEPOSIT.

Doctor Newberry, as an advocate of the ascension theory, differs from Mr. S. F. Emmons and Mr. Becker, who lean toward the *lateral secretion* theory, and who, in their examination respectively of the Leadville and Comstock ore deposits, attribute the ores to the leaching of adjacent *igneous rocks.* He differs with them for the following reasons:

"First—The great diversity of character exhibited by different sets of fissure veins which cut the same country rock seems incompatible with any theory of lateral secretion.

"These distinct systems are of different ages, of diversified composition, and have drawn their supply of material from different sources. For examples, the Humboldt, the Bassick and Bull Domingo, near Rosita and Silver Cliff, Colorado. These are veins contained in the same sheet of eruptive rock, but the ores are as different as possible. The Humboldt is a narrow fissure, carrying a thin ore streak of high grade, consisting of sulphides of silver, antimony, arsenic and copper. The Bassick is a great conglomerate vein, containing tellurides of silver and gold, argentiferous galena, blende and yellow copper pyrites. The Bull Domingo is also a great fissure, filled with rubbish, containing ore chimneys of galena, with tufts of wire silver." Many other groups of mines are also cited, showing that the same rocks are cut by veins of different ages, having different bearings and containing different ores and veinstones. "It seems impossible that all these diversified materials should have been derived from the same source, and the only explanation is *the ascent of metalliferous solutions from different and deep seated sources.*

"These and all similar veins have certainly been filled with material *brought from a distance* and *not derived from the walls.*"

LEACHING OF IGNEOUS ROCKS.

Against the theory that mineral veins have been produced by the leaching of superficial *igneous* rocks, he says:

"Thousands of mineral veins the world over occur in regions remote from eruptive rocks," and cites a great number of examples. "In the great mineral belt of the Far West, where volcanic emanations are so abundant, and where they have certainly played an important part in the formation of ore deposits, the great majority of veins are not in *immediate* contact with trap rocks, and they could not, therefore, have furnished the ores." He cites several examples, and amongst them "the gold mines of Black Hawk, Colorado, the Montezuma, Georgetown, and other silver mines in the granite belt of Colorado. In nearly all the localities cited we may find evidence of not only that the ore deposits have not been derived from the leaching of *igneous* rocks, but also that they have not come from those of any kind which form the walls of the veins.

"The gold bearing quartz veins of Deadwood, (Black Hills) Dakotah, are so closely associated with dikes of porphyry that they may have been considered as illustrations of the potency of trap dikes in producing concentration of metals. But we have evidence that the gold was there in Archœan times, while the igneous rocks are all of modern, probably of Tertiary date. This is shown in 'the cement mines' of the Potsdam Silurian sandstone. This is the beach of the lower Silurian sea when it washed the shores of an Archœan island, now the Black Hills. The waves that produced this beach beat against cliffs of granite and slate, containing quartz veins carrying gold. Fragments of this auriferous quartz and the gold beaten out of them and concentrated by the waves, were in places buried in the sand beach in such quantity as to form deposits, from which a large amount of gold is now being taken. Without this demonstration of the origin and antiquity of the gold it might very well have been supposed to be derived from the eruptive rock."

Again he says: "That where igneous rocks are most prevalent such districts are proverbially barren of precious metals, and where these metals do occur in such districts the same sheet of rock may contain several systems of veins with different ores and gangues." He cites the great lava plains of Snake River, of Eastern Oregon, Northern California and New Mexico as unproductive generally of ore deposits. Also the great lava plateaus of the Cascade range. On the other hand the Sierra Nevada, composed principally of *metamorphic* rocks, contains vast quantities of gold, silver and copper.

"At Lake City, in the San Juan district of Colorado, the prevailing porphyry holds the veins of the 'Ute' and 'Ulay' and 'Ocean Wave' mines, which are similar, whilst the 'Hotchkiss' and 'Belle' are entirely different. We have no evidence that any volcanic eruption has drawn its material from zones or magmas especially rich in metals or their ores. And on the contrary volcanic districts like those mentioned, and regions such as the Sandwich Islands, where the greatest eruptions have taken place, are poorest in metalliferous deposits."

He remarks that igneous rocks in our Western territories are "but fused conditions of sediments forming the underlying structure of that country." [They may be fused archœan granitic rocks, but certainly not the higher series of silurian, carboniferous and palœozoic rocks, for the simple reason that at Leadville and in our western region we can readily trace the vents or dykes from which this eruptive rock came up, penetrating deep into and lost in unknown depths of the granite, and thence rising and spreading over and intruded into the overlying Paleozoic rocks, as its source is evidently far beneath these overlying rocks, its material could not have been derived from them.]

"Over the great mineral belt which lies between the Sierra Nevada and the front range of the Rocky Mountains, and extends not only across the whole breadth of that region, but far into Mexico, the surface was once underlain by a series of Paleozoic sedimentary strata, not less than twenty thousand feet in thickness, and beneath this were Archœan rocks, also metamorphosed sediments. Through these the ores of the metals were generally, though sparsely, diffused. In the convulsions which have in recent times broken up this long quiet and stable portion of the earth's crust, (and which have resulted in depositing in thousands of cracks and cavities the ores we now mine) portions of the old table land were in places set up at high angles, forming mountain chains and doubtless extending to the zone of fusion below. Between these blocks of sedimentary rocks oozed up through the lines of fracture, quantities of fused material, which also sometimes formed mountain chains, and it is possible and probable that the rocks composing the volcanic ridges are but phases of the same materials that form the sedimentary chains." [Of the granite, perhaps, but not of the limestones.] "There is no particular reason why the leaching of one group should furnish more ore than the other, but as a fact the unfused sediments are much the richer in ore deposits. This is to be accounted for by supposing that they have been *the rceptacles of ore brought from a foreign source.* We conclude that there has been a zone of solution below, where steam and hot water, under great pressure, have effected the leaching of ore bearing strata, and a zone of deposition above, where cavities in preexistent, solidified, and shattered rocks became the repositories of the deposits made from ascending solutions when the temperature and pressure were diminished. Where great masses of hot lava were poured out, these for a long time remained too heated for ore deposition. So long, indeed, that the period of active vein formation may have passed before they reached a degree of solidification and coolness that would permit their becoming receptacles of the products of deposition. The masses of unfused cooler sedimentary rocks forming the most metalliferous mountains were, throughout the period of disturbance, in a condition to become such repositories. Highly heated solutions, forced by an irresistable power through rocks of any kind down in the heated zone, would be far more effective leaching agents than cold surface water, with feeble solvent power, moved only by gravity, percolating slowly through superficial strata.

"Richtofen suggested that the mineral impregnation of the Comstock lode was the result of the leaching of deep seated rocks, perhaps the same that enclose the vein above, by highly heated solutions which deposited their load near the surface.

"Becker supposes the ore concentration to have been effected by surface waters flowing laterally through the igneous rocks, gathering the precious metals and depositing them in the fissure, as lateral secretion produces the accumulation of ore in the limestone of the lead region."

Prof. Newberry thinks Richtofen's theory the most probable of the two.

"For, first, the veinstone of the Comstock is chiefly quartz, the natural, common precipitant of hot waters, since they are far more powerful solvents of silica than cold waters. The ores deposited in the Mississippi lead region at low temperature contain little silica.

"Second—The great mineral belt alluded to between the Rockies and Sierra Nevada is now the region where nearly all the hot springs of the continent are situated. It is evident that these are the last of the series of thermal phenomena connected with the great volcanic upheavels and eruptions, of which this region has been the theatre since the beginning of the Tertiary age, and it is evident that the number of hot springs in this region was once far greater even than it is now. That these hot springs were capable of producing mineral veins by materials brought up in and deposited from these waters, is demonstrated by the phenomena of the Steamboat Springs, where we have the best illustration of vein formation now in progress. The temperature of the lower workings of the Comstock mine is now over 150° F., and an enormous quantity of hot water is discharged through the Sutro tunnel. This water has been heated by coming in contact with hot rocks at a lower level than the present workings of the Comstock lode, and has been driven upward in the same way that the flow of all hot springs is produced. As that flow is continuous it is evident that the workings of the Comstock have simply opened the conduits of hot springs, which are doing to-day what they have been doing in ages past, but much less actively, that is, bringing toward the surface the materials they have taken into solution in a more highly heated zone below. Hence it seems more natural to suppose that the great sheets of ore bearing quartz now contained in the Comstock fissure were deposited by *ascending* currents of hot alkaline waters than by *descending* currents of those which were cold and neutral. The hot springs are there, though less copious and less hot than formerly, and the natural deposits from hot water are there. It seems more rational to suppose, with Richtofen, that these are related as cause and effect rather than that cold water has leached the ore and the silica from the walls near the surface. The fissure was for a long time filled with a hot solution charged with an unusual quantity of the precious metals, and the presence of gold in the wall rock is due to their being partly impregnated with the same solution.

"At Leadville there are no facts to prove that the ore deposits have been formed by the leaching of the overlying porphyry rather than by an outflow of heated mineral solutions along the plane of junction between the porphyry and the limestone. Near this plane the porphyry is often thoroughly decomposed, is somewhat impregnated with ore, and even contains sheets of ore within itself; but remote from the plane of contact with the limestone it contains little diffused and no concentrated ore. It is scarcely more pervious than the underlying limestones, and why a solution that could penetrate and leach ores from it should be stopped at the upper surface of the blue limestone is not obvious. Nor why the plane of junction between the porphyry and the blue limestone should be the special place for the deposit of the ore."

In place of Mr. Emmons' theory of the leaching of the porphyry by waters from above, etc., Prof. Newberry thinks that the Leadville ore deposits "can be better accounted for by supposing that the plane of contact between the limestone and porphyry has been the conduit through which *heated* mineral solutions, coming from deep seated and remote sources, have flowed, removing something from both the overlying and underlying strata, and, by substitution, depositing sulphides of lead, iron, silver, etc., with silica."

If the porphyry is so rich in precious metal as Mr. Emmons' assays report it to be, Prof. Newberry thinks it "a remarkable and exceptional case of the diffusion of silver and lead through igneous rocks." He thinks it possible that the Leadville porphyries are phases of rock rich in silver, lead and iron, which underlie this region, and which have been fused and forced to the surface by an ascending mass of deeper seated igneous rock; "but even if the argentiferous character of the porphyry shall be proven, it will not be proven that such portions of it as here lie upon the limestone have furnished the ore by the descending percolation of cold surface waters. Deeper lying masses of this same silver, lead and iron bearing rock, digested in and leached by hot waters and steam, under great pressure, would seem to be a more likely source of the ore." He argues also that if the overlying porphyry had yielded, by leaching, such enormous bodies of metal as we find in the Leadville ore bodies, we should find the porphyry a much more rotten, "digested kaolinized and desilicated rock than it is. As a rule it is generally quite compact, except in a narrow line near the ore body, where it is much decomposed, probably by hot chemical solutions forced up from below, along the plane of contact. It is difficult to understand why the upper portion of the porphyry should be so solid and homogeneous, with no local concentrations or pockets of ore, if they have been exposed to the same agencies as those which have so changed the under surface."

He thinks also that if the ore bodies were derived by leaching of the porphyry by surface waters, there ought to be evidence of its continuing in the present day as it does in some galena mines. Dr. Newberry admits, in a modified form, the general truth of a "lateral secretion" theory in some instances, but does not think that the vein materials are necessarily derived from the wall rock immediately opposite the places where the ore is found. He considers the main influence of igneous rocks is rather in supplying heat to the solutions than directly supplying the elements of the ore, and he mentions a case in Utah where ore bearing quartz veins come up on either side of an unaltered, hard dyke of igneous rock, from which there is no evidence that they derived either their quartz or their metal from the dyke or adjacent limestone, but from heated solutions ascending from a deeper source and bringing up foreign material with it. He considers Richtofen's theory of the filling of the Comstock to be the true one, and the phenomena furnished by Steamboat Springs to give us the typical mode in which most metallic veins were formed and filled.

LE CONTE'S THEORY.

Professor Le Conte, in his geology, says of fissure veins, that they are fillings of great fissures, produced by movements of the earth's crust. When these fissures are filled, at the time of formation by igneous injection, they are called dykes, when subsequently with mineral matter by a different and slower process they are fissure veins. They often outcrop like dykes for miles over the surface of the country by reason of their superior
ness to the enclosing country rock, and extend to unknown but

certainly very great depths. They also occur in parallel systems.

The leading characteristics of true fissure veins he defines to be:

1. Their continuity for great distances and to great depths.

2. Their occurring in parallel systems.

3. Their filling a preexistent fissure, the distinction between vein and wall-rock being usually quite marked.

4. The presence of selvage or gouge between the gangue and the country rock, which he attributes to water circulating in the fissure.

5. Their contents are more varied than those of other classes of ore deposits.

He distinguishes *infiltration veins* and *great fissure veins*, the former occupying a small short crack in the strata, and deriving its filling from material oozing from the sides by *lateral secretion* from a single variety of rock. The latter occupy great and deep fissures, and derive their contents from *all* the strata to great depths, and especially from the deeper *strata*. Hence the contents of these veins are more varied.

"The contents of mineral veins were deposited by hot alkaline solutions coming up through fissures, in other words hot alkaline springs. Deposition by solution is proved by the occurrence of banded or ribbon structure and interlocked crystals and combs, by quartz forming the gangue, and that quartz of the kind known to be only formed by water solutions by its containing bubbles of water inside it, etc.

"That the solutions were hot is implied by the great depth to which the fissures are known to descend and the regular increase with depth, of the heat of the earth. Hot water is also a most powerful solvent. That the solutions were alkaline is implied by the fact that alkaline sulphides and carbonates are the only solvents of quartz. The same character of water when carbonic acid is in excess, dissolves carbonate of lime and baryta, the other common forms of gangue. Hot springs of this kind in Nevada are to-day depositing quartz and iron and lime and filling fissures."

He considers that the ore or metal materials came in with the same solutions that brought in the dissolved quartz, lime or baryta gangue. He considers that great fissures have been formed by deposit from hot alkaline waters holding various mineral substances in solution. The more insoluble substances are deposited in the vein, while the more soluble reach the surface as mineral springs, and he quotes the already described phenomena of the Steamboat Springs, near Virginia City, Nevada, as a fissure vein forming before our eyes, and explaining to our vision the way in which fissure veins have in former ages probably been formed.

He sums up by saying that: "Meteoric waters circulating in the interior of the earth in any direction, downward, upward, or laterally, deposit slightly soluble matters in their course, in cracks, cavities or great fissures, forming fossil casts, geodes, amygdules, infiltration veins and fissure veins.

"As to direction—the up-coming waters, especially in metamorphic and volcanic regions, deposit most freely, because they are hot and alkaline, and therefore powerful solvents and cool gradually on approaching the surface. But that downward percolating waters may also deposit metallic ores is proved by the fact that these are sometimes found hanging like stalactites from the roof of cavities. The great fissure veins are the most prolific because these fissures are the highways of water from the heated depths. But every kind of water-way will receive deposits, and as the kinds of these are infinitely various, and pass by insensible gradations into each other, so also will be the veins that fill them. The open fissure is the easiest, and therefore the most traveled highway. In these, therefore, we have the most perfect type of veins, with their banded structure, their selvages (or gouge), their great size and continuity. But in many cases crust movements produce only slight fissures or loosening of the rocks along planes full of small cracks with country rock between. These loosened planes become also water-ways, and, by deposit, form those irregular veins so common everywhere, but especially in the cinnabar veins of California

"Or again, crust movements may produce not clean, open fissures, but rather planes of shattered rock like fissures filled with rubble. Deposits in such a water-way forms a breccia of country rock, cemented with vein stuff.

"Or again, in certain country rocks, soluble in water, especially limestones, the rock is dissolved along the water-way and the vein stuff deposited 'pari passu,' giving us the ***substitution veins.*** In short, if one can conceive clearly that mineral veins are filled water-ways, all these complex phenomena solve themselves."

DESCRIPTION OF FRONTISPIECE.

The frontispiece represents both sides of the Roaring Fork Valley in which Aspen city is situated, and also looks up toward the Grand Cañon of Roaring Fork, where the river issues through its walls of granite in the Sawatch Range. On the right hand side of the picture we see Aspen Mountain on which are so many of the principal mines. These are located principally on the slope of Spar Gulch and in the bed of the adjacent Vallejo Gulch. In the Spar Gulch are the Durant and other "Apex" mines, and in Vallejo are the principal "Sideline" mines, both working in the same uplifted belt of carboniferous limestone and both, happily, of late consolidated by a compromise. The centre of Vallejo Gulch is occupied by a great thickness of eruptive diorite lying more or less upon top of the basined and faulted limestone, and separated from it by a belt of black shale. On the opposite side of this, on the right, the limestone again appears by a process of folding and faulting, and is pierced by several tunnels, amongst them the Late Acquisition and Pioneer Mines. The limestone and some quartzite rest upon granite which forms the central nucleus or basis of the mountain which, as the engraving shows, is hollowed out into a thin shell like the half-section of the crater of a volcano. On the north-western slope of this shell are seen the same silurian quartzites and overlying carboniferous limestones leaning against and folding around the granite with a somewhat different direction of strike and dip from the beds on the opposite side of the shell in Spar Gulch. Ore deposits are found on this side also, but not so abundantly as on the other; the Pride of Aspen, Mary B and Homestake tunnels have found ore. Beneath this slope is Castle Creek, flowing into the Roaring Fork. This side of the Roaring Fork, together with the city of Aspen as it appeared two years ago when the writer sketched it, together with the principal mines on Aspen Mountain are best shown in the sketch on page cxx, with the accompanying section. On the left hand of the frontispiece, the small but important hill called Smuggler Mountain is seen. Its importance consists in the rich developments of ore that have been found in the Smuggler, J. C. Johnson and Regent mines, all of them, as on the opposite mountain, apparently on the same line of contact. The geology of this mountain is somewhat obscured by enormous coverings of glacial drift, but from the developments in the mines it appears to correspond to the same formations as are more clearly developed on the opposite Aspen Mountain in Spar Gulch. The mountain is of less size than that of Aspen Mountain apparently from the strata not being there reduplicated by faulting, as on Aspen Mountain, but formed of a single series of strata consisting of silurian quartzites resting on granite, with dolomitic limestone (short limestone) and black shales above them, and also some diorite porphyry (if we may judge from materials found in the dumps) included, as on the other side, in the black shales. Though the ore bodies are well developed in the mines and of much the same character as on Aspen Mountain, the presence of the blue limestone of Spar Gulch is not so apparent; its seeming absence might be accounted for by its having been more completely dolomitized on this side than on the other, or by its having been partially or completely eroded away or even replaced by ore, rather than to suppose the strata is different or the ore belt at a different level on this side than on the other. It is probable that a fault corresponding with the bed of Roaring Fork will be found to separate this mountain from Aspen Mountain. The dip of the strata, as shown in the J. C. Johnson mine, is much steeper than that on Aspen Mountain, and increases in steepness with depth. The strata on the opposite side of Hunter's Creek are red sandstones, and probably belonging to the Jura-Trias, or extreme upper Carboniferous. In the foreground is a pretty little artificial lake, a favorite resort of the Aspenites. Behind the lake appear some of the houses on the skirts of the city.

SAN JUAN FISSURE VEINS. (Page 72.)

The illustrations, Figs. 1 and 2, representing "horses" in great fissure veins, were from sketches by the writer, of some fissure veins in the Animas Cañon, between Silverton and Animas Forks. The veins are of great width, from 50 to 100 feet in places, and are clearly defined on the side of the cliffs of the cañon, whose height is between 2,000 and 3,000 feet. Fig. 3 is from Dr. Hayden's report, of two series of fissure veins cutting one another diagonally, opposite Howardsville, in the same cañon. Two mammoth master veins are cut by a series of minor fissure veins having a different direction or strike.

SHEEP MOUNTAIN FOLD AND LONDON FAULT. (Page 33.)

The picture of the "Sheep Mountain fold and London fault" is a striking example of structural geology, showing how a mountain range, such as the Mosquito Range, is formed by a series of folds, passing at their greatest tension into profound fractures or faults, resulting from tangential pressure or compression, whose ultimate cause, is the gradual contraction of the earth's crust around its diminishing cooling nucleus.

It is not often that nature supplies us with so remarkably clear a section of her hidden structure as that presented in the Sheep Mountain fold in Horseshoe Gulch. The hard Silurian quartzites, together with the overlying Carboniferous sandstones, shales and limestones, and a cap of white porphyry, are seen bending over in a steep but complete arch almost as perfect to the eye as one formed of artificial masonry.

The exact line of the London fault, which is indicated by the little valley or sag between it and the adjoining Lamb Mountain, is, as is usual in the case of faults, obscured by debris and vegetation. If the debris were removed we should probably find the fold passing into an S-like form, broken near the base by a nearly vertical crack, with Silurian strata and Archæan granite forming the east wall of the crack abutting against upper Carboniferous grits on the west wall of the fissure. There is consequently a slip here of many hundreds of feet. Some idea of the amount of slip may be obtained by noticing that the Weber grits of the upper Carboniferous, marked g, lie properly on top of Sheep Mountain. The fault has dropped them down to the bottom of the valley, where the upper portion of them is seen outcropping at the base of the adjacent Lamb Mountain. A portion of them, turned up by the fault at a sharp angle, is observable on the east side of Lamb Mountain, reclining against eruptive white porphyry. In the grits and shales were found well defined impressions of true Carboniferous foliage, such as the Equiseta. The top of Lamb Mountain gives us a good example of a laccolite of eruptive white poryhyry, from which the overlying and once over-arching sedimentary strata have been removed by erosion. A dyke of white poryhyry is found cutting through the underlying strata and connecting with the great laccolitic mass, which rests intrusively on the Weber grits. This is one of the numerous vents from which the great white porphyry sheets came.

SUMMIT OF MT. LINCOLN. (Page 49.)

Mt. Lincoln is a typical example of a mountain formed by a net work of dykes and branching sheets of hard porphyry intruded between less enduring strata of silurian quartzites and carboniferous limestones, welding together the mass into a compact form which has resisted erosion and left a prominent peak 14,000 feet above sea level and 4,000 feet above the adjacent valleys of erosion. A dyke of coarse grained quartz-porphyry, containing large perfect crystals of feldspar, has come up through the granite, piercing also the overlying paloeozoic strata, sending out intrusive sheets, and near the top intruding an enormous thick reservoir mass between the strata, in the form of a laccolite, from which the overlying and once over-arching strata has been removed, leaving the great columnar mass exposed, which now forms the summit of the peak. This dyke has also been cut by newer dykes and sheets of a dark green porpyhry called porphyrite, which has also sent out horizontal sheets between the silurian strata, and these sheets have again been cut by a dyke of white porphyry. The feeding dykes of both forms of porphyry are here traceable down into the granite forming the base of the mountain. The principal ore belt, upon which the Russia, Present Help and other mines are located, is near the summit of the mountain, at the contact of a porphyry sheet with the carboniferous limestone. The Present Help mine is one of the highest in the world.

THE COLORED GENERALIZED SECTION OF THE ROCKY MOUNTAINS IN COLORADO, SHOWING THE POSITION OF ECONOMIC PRODUCTS IN THE DIFFERENT GEOLOGICAL HORIZONS AND STRATA. (Page cxxviii or 128.)

This section, which illustrates portions of Part I. and II. of this treatise, represents a general average section of the Rocky Mountains in Colorado, made up from typical sections of the country where the strata are best exposed.

Thus the Archæan may be exemplified by the Sawatch and portions of the Mosquito ranges.

The Paloeozoic, consisting of the Silurian and Carboniferous, by the Leadville, South Park and Aspen districts.

The Triassic and Jurasssic, by the rocks of Morrison or by the Garden of the Gods at Manitou.

The Lower Cretaceous, to the Laramie coal beds, also by the section near Morrison, along the banks of Bear Creek.

The Laramie Cretaceous, including the coal beds, by the section at Golden City, along the banks of Clear Creek.

The Tertiary, by the table lands or "mesas" of the Divide near Sedalia.

The Quaternary and Tertiary, by the strata underlying Denver and forming the Denver basin. The Quaternary pebble beds are distributed at intervals over the eroded tops of all the formations from Archæan to Tertiary, and from the high mountain placers in glaciated cañons to where the principal streams debouche on the prairies.

The *Archæan* is shown to consist of granite, gneiss, schist, etc., traversed by dykes of eruptive rock and by fissure veins carrying silver, gold, lead and iron, and constitutes the axis of the high mountain region.

The Silurian and Carboniferous, constituting the Paloeozoic era, rest on the granite, and are traversed by various eruptive porphyries issuing from the underlying Archæan, in dykes, and spreading out between the Paloeozoic strata in intrusive sheets, or in thick laccolitic masses, sometimes by erosion, forming the caps or peaks of prominent mountains. The quartzites are shown to be principally gold bearing and the limestones silver and lead bearing, particularly at their contact with eruptive porphyries.

Iron is found throughout the series. The great thickness of *Weber grits*, consisting of coarse sandstones, shales and quartzites, with a few limestones, are generally unproductive. A few thin seams of semi-anthracite coal occur at Aspen and Leadville, and towards the upper portion some limestones, penetrated by porphyries, produce important deposits of silver and lead in the Ten-Mile district at Kokomo, of which the Robinson mine may be taken as typical.

The Paloeozoic rocks are generally confined to the high mountain region.

The *Mesozoic* rocks, consisting of the Trias, Jurassic and Cretaceous, are more characteristic of our foothills and hogbacks, and yield us no precious metals, but many valuable economic products.

The Trias yields good red building stone at the Glencoe quarries, on Ralston Creek; also white silicious sandstone for glass manufacture, and red flagging stone in Boulder County.

The *Jurassic* yields quicklime from quarries in limestone, at several points along the foothills; also beds of gypsum for plaster of paris, and some fine red building sandstone. The formation is remarkable for the dinosaurs, discovered at Morrison and Cañon City, and for the first discovery of oil on Oil Creek, near Cañon City.

The base of the Cretaceous, called the Dakotah group, consists of a thick bed of white sandstones, quarried at Morrison for building stone, and in the center of the group is a belt of the finest blue fireclay in America, quarried between Golden and Morrison, and extensively used for fire brick, etc. This formation generally forms a prominent hogback along our foothills.

The *Colorado Cretaceous* consists first, of a bed of black shale, with concretions of inferior iron ore; secondly, of white limestone, much quarried along the foothills at Golden, Morrison, Cañon and elsewhere for flux for the smelters; thirdly, a bed, sometimes over 2,000 feet thick, of drab shales and clays, near the middle of which is a sandy layer, which has been tapped by the oil wells of Florence, near Cañon City, and has so far yielded most of our oil production.

The *Laramie Cretaceous* has a thick bed of white sandstones near its base, which is utilized for building sandstone, and quarried at Trinidad, Cañon City and elsewhere. In this sandstone formation lie the principal coal seams, the largest and most worked averaging 6 to 8 feet in thickness. Beds of inferior concretionary iron ore are also found near the coal, and also beds of plastic clay and inferior fire clay.

The *Tertiary* beds of clays and sandstone, underlying Denver, have given us our artesian wells, at depths varying from 300 to 1,000 feet, and on the Divide, between Denver and Colorado Springs, the Tertiary table lands are capped by a pink rhyolite lava, much used as building stone.

The *Quaternary*, consisting of drift, pebbles and clay, can be found on the banks of our streams and underlying our farm lands, or on the sides of the deep canons on the high mountain areas. It forms our placer beds, which yield more or less gold, and in several localities the fine clay makes good red building brick. Above this rests the black soil of the farm lands, with their crops of grain, grass and vegetables.

This section can be applied, with modifications, in a general way, to various parts of Colorado, and may act as a rough guide or map to the prospector in search of precious metals or other economic products.

SECTIONS ILLUSTRATING THE GRADUAL DEVELOPMENT OF THE LEADVILLE AND SOUTH PARK REGION. (Page cxii or 112.)

Figures 1 and 2 are ideal, and meant merely as illustrations of Mr. Emmons hypothesis, with a view to make the text more clearly understood.

Fig. 1 represents all the strata, from Silurian to Cretaceous, as lying conformably on one another at the bottom of the Cretaceous sea, between two granite islands—the one on the right constituting the "nucleus" of the modern Front Range, the one on the left of the Sawatch Range. Between the two is the area now occupied by the South Park, the Mosquito Range, the Leadville district and the Arkansas Valley. These conformable strata were, according to Emmons, penetrated by dykes and intrusive eruptive sheets whilst lying below the sea, and mineralization took place about the same time.

Fig. 2 shows all these strata, with their included eruptive sheets and ore beds, crumpled up between the Front Range and the Sawatch Range into the Mosquito Range and South Park basin, which took place at the great mountain uplift at the close of the Cretaceous.

Fig. 3 is an actual average section of the region of South Park and the Leadville district as it now is, showing how the folds passed into faults, and how the tops of the folds and uplifted cliffs of the faults have been planed down by erosion.

The figures also show in somewhat the same way the progressive history of the eastern and western foothills on either side of the granite axes; how they were originally horizontal, how they were folded up and how, by erosion, they have been cut down into low hogbacked ridges.

INDEX OF CONTENTS.

PART I.

PART II.

PART III.

APPENDIX.

INDEX OF ILLUSTRATIONS.