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MILITARY SKETCHING
MADE EASY,
AND
MILITARY MAPS
EXPLAINED.

BY

COLONEL H. D. HUTCHINSON,
INDIAN ARMY

(Now Major-General H. D. Hutchinson, C.S.I., late Director of Staff Duties).

Author of "*Field Fortification: Notes on the Text Books*," "*The Story of Waterloo*," *&c., &c.*

SEVENTH EDITION.

REVISED AND BROUGHT UP TO DATE

BY

MAJOR R. F. PEARSON,
THE BUFFS.

Author of "Military Panorama Drawing in Three Lessons."

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PREFACE TO THE FOURTH AND FIFTH EDITIONS.

It is very gratifying to me to find that after a probation of more than FIVE years, "Military Sketching Made Easy" is still a favourite with the Army, and continues in greater demand than ever.

The great success this little book has from the first met with, in the face of great competition, is sufficient proof, if any were wanted, that the real art of teaching, and of making a study attractive, is to MAKE IT EASY. This has always been my first aim throughout my career as an Instructor, and as an Author.

To this new edition an essay has been appended on the use of the "Cavalry Sketching Case," written by a relative, who has had great experience in using it. It originally appeared in the Journal of the United Service Institution of India, and will be found thoroughly practical, very clear, and of great value.

H. D. H.

March, 1891.

PREFACE TO THE SIXTH AND SEVENTH EDITIONS.

Owing to several changes it has been found necessary to issue a new edition of "Military Sketching Made Easy." It has now been thoroughly revised and brought up to date with the latest Official Text Books on the subject. A new chapter on Military Freehand Drawing has been added, which, it is hoped, will be found useful by all interested in the study of Topography.

R. F. PEARSON, Major.

PREFACE TO FIRST EDITION.

My chief object in writing this Book has been to make the theory and practice of "Military Sketching" EASY for those whose duty, interests, or inclination, may lead them to study the subject. My experience is that if any study is made easy, the learner's interest in it is soon aroused, and *that* once secured, his progress, and a certain amount of proficiency, are assured. But, if at the outset, difficulties, and technicalities hard to understand, are encountered, discouragement, and sometimes even disgust, will result. Then, as a natural consequence, many men will make up their minds to learn just as much, or just as little, of the subject, as will get them through their examinations, or serve their immediate purpose, and no more, and this being accomplished, they let it drop for good. This is a pity, but it is nevertheless true; and though these remarks apply to all studies, they refer peculiarly to the art of Military Sketching, because apart from the theory of it, there is the practical out-door work to be done, and this becomes most laborious, and must be extremely barren of result, unless the whole subject has been previously attentively, and intelligently studied. Such study is, I venture to say, unusual, and simply because it is found difficult, without assistance, which is not always forthcoming. There are many excellent books extant on Military Surveying and Sketching, but I think that with the majority of them, it is too much taken for granted that those who approach the subject are already either grounded in its principles, or can count on obtaining the help of an expert to explain difficult passages. This is a mistake. In the first place, there are many men in the service, who either have never been taught the rudiments of Military topography: or, who having been instructed as Cadets at Sandhurst, or Woolwich, have managed in the course of a few years, to forget all that they ever learnt, But, besides this, there is a tendency with officers of every grade, even if they have been through a course of instruction, to lay aside study when there are no longer examinations to be passed. Now I believe they do this simply because when their knowledge begins to get a little rusty, and they no longer have instructors to help them, they cannot find in their library just those practical hints and examples that they require to keep themselves up to the mark. Or possibly, the explanations given are a little bit too technical for them. My idea, therefore, has been to supply this want. In the following pages, every explanation has been given in the fewest and plainest words ; and whenever it was possible, I have given *worked-out examples* of almost every kind of question that could arise in practice. I have carefully avoided all technicalities, and have confined the scope of the work (with one exception—the Pocket Sextant) strictly to those points with which it may be reasonably expected a Regimental Officer should be conversant. I hope, notwithstanding, that even Staff Officers, and others, may find here and there a useful hint in its pages.

A work of this kind can, of course, be little more than a compilation ; but it will be noted that the arrangement of the subject is new, and different to any hitherto adopted. I think it will be found a practical and convenient one. One chapter is devoted to giving simple and concise *definitions* of special terms and phrases used in connection with Military Sketching. I believe a good definition to be an important step towards getting a clear idea of any matter, so I hope this chapter will be found useful.

With reference to the use of the Pocket Sextant and Chain, it may be remarked, that it is only under exceptional circumstances, that a Regimental Officer would have to work with them. Nor is an acquaintance with them included in the requirements for Sandhurst or promotion examinations. But I have described them, and their uses, because no book on Military Sketching would be complete without them, and because their use can be so easily learnt, and might on many occasions be of the greatest value. Those, however, who prefer to do so, can omit the chapters describing them, or leave their study to the last. For the same reasons the Sections on Vernier Scales may be passed over.

In conclusion it may be noted that the contents of this book are in thorough conformity with the Authorised Text Book of Military Topography.

H. D. HUTCHINSON.

Bengal Staff Corps

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MILITARY SKETCHING MADE EASY,

AND

MILITARY MAPS EXPLAINED.

CHAPTER I.

SCALES.

A Scale is a statement of the proportion between a map, or plan, and the ground which it represents. This statement may be made, or shown in various ways:—

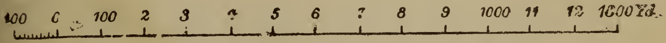
(*a*). By a statement in words: *e.g.*, it may be stated on the face of a map that the scale is 6 inches to a mile.

(*b*). By a Representative Fraction: *e.g.*, it may be marked on a plan that its R.F. is $\frac{1}{10560}$.

(*c*). By a line divided into several equal parts, and figured thus:—

(Fig. 1.)

In all military sketches it is usual to give all three ways, and a scale to be complete should be drawn, and figured, thus:—



Scale of Yards, 4 in. to a Mile R.F. $\frac{1}{15840}$.

(Fig. 2.)

A Representative Fraction is a fraction of which the numerator bears the same proportion to the denominator, that the map, or any distance on it, bears to the ground that it represents. Thus, if the R.F. of a map is $\frac{1}{63360}$, it means that 1 inch on the map represents 63360 inches, (*i.e.* one mile) of the ground. The numerator of the R.F. must always be 1, and this 1 is always taken to mean 1 *inch*, therefore the denominator must, of course, be invariably expressed in inches.

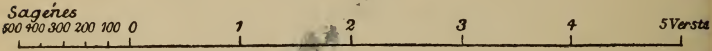
Examples. (1). *The scale of a map is* 3 *inches to a mile Give its R.F.*

$$\text{R. F.} = \frac{3 \text{ inches}}{1 \text{ mile}} = \frac{3}{1 \times 1760 \times 3 \times 12} = \frac{1}{21120} \quad \textit{Ans.}$$

(2). *You measure the distance between two villages, and find it to be* 1500 *yards: on a map of the ground they are shown exactly* 4.3 *inches apart. What is the R.F. of the map?*

$$\text{R.F.} = \frac{4.3 \text{ inches}}{1500 \text{ yds.}} = \frac{4.3}{1500 \times 3 \times 12} = \frac{4.3}{54000} = \frac{1}{12558.1} \quad \textit{Ans.}$$

It is to be noted that if the Representative Fraction is marked on a sketch, the scale can be understood, and the sketch can be used, by anyone, even though it be a foreign one; whereas without the R.F. it might be useless. For example, suppose a Russian sketch to fall into your hands with the subjoined scale given on it showing *versts*—



(Fig. 3.)

It would be no use to you for calculating distances, or marches, unless you happen to know how much a verst is. But if, in addition to the scale, the R.F. is marked, thus—$\frac{1}{72000}$ then at once you see that the scale of the sketch is 2000 yards to an inch, and you can make your calculations accordingly.

The size of the scale employed depends upon the work in hand. If great accuracy of detail is required, the scale must be a large one. If minutiæ need not be attended to, the scale may be small. For example, for the plan of a building, the scale might be as much as 4 ft. or 5 ft. to an inch: for a village or town, it might be from 50 to 200 yards to an inch. For military purposes the following scales may serve as a guide :—

For a road or river reconnaissance, 1 to 2 inches to 1 mile ($\frac{1}{63360}$ to $\frac{1}{31680}$). For a sketch of a district, $\frac{1}{4}$ to 1 inch to 1 mile ($\frac{1}{253440}$ to $\frac{1}{63360}$). For an outpost or defensive position, 2 to 4 inches to 1 mile ($\frac{1}{31680}$ to $\frac{1}{15840}$). For a sketch of a town or village required to be defended, 4 inches to 1 mile and upwards ($\frac{1}{15840}$, etc.).

It may be noted that the usual scales for German military maps are:—

For roads and rivers $\frac{1}{25000}$, which is rather more than $2\frac{1}{2}$ in. to a mile. For positions $\frac{1}{12500}$, which is rather more than 5 in. to a mile. For tracts of country $\frac{1}{80000}$, or $\frac{1}{100000}$, less than 1 in. to a mile.

GENERAL RULES APPLICABLE TO ALL GEOMETRICAL DRAWING.

(*From the Roorkee Manual*).

1.—Never draw a single line that is not absolutely necessary: therefore do not commence operations hastily, without well considering the proceeding, and while drawing with a pencil, use one cut to a fine point, and press very lightly upon it; the pencil lines need be only just visible, and by attending to this the paper is kept cleaner, and the constructions are made more accurately.

2.—When about to draw a right line between two points, place the ruler as nearly as possible in the same position with reference to both, and then see whether the line will pass exactly through both points, before drawing it on the paper with either pen or pencil.

3.—All lines should be drawn sufficiently long at first, to avoid the necessity for subsequently producing them; a long line should never be obtained by producing a short one, unless some distant point in the prolongation has been first found by other means.

4.—Whenever it is practicable, lines should be drawn *from* a given point and *not to* it; and if there are several points, in one of which two or more lines meet, the lines should be drawn from that one to the others: thus, radii of a circle should be drawn from the centre to points in the circumference.

5.—The larger the scale on which any problem, or part of one, is constructed, the less liable is the result to error. Hence all angles should be set off, and points determined, by means of the largest circles which circumstances will allow to be described.

6.—In determining a point by the intersection of circular arcs, or straight lines, these should meet at that point at an angle of not less than 30°.

7.—When one arc, or straight line, intersects another, as above, the point of intersection only of the second one with the first need be marked, to avoid unnecessary lines.

8.—Avoid setting off equal lengths on a given straight line by continual repetition of one such length, but mark off, on the line, a convenient multiple of the given length and sub-divide it, *i.e.*, work from the whole to parts, not from parts to the whole; this is a great principle in surveying as well as plan drawing, and is especially to be observed in the construction of scales.

9.—In laying off a length along a line with a scale, it is always well to check, either by reading off the distance along another part of the same scale or by applying it so that it shall read backwards. This is a simple check, and a very useful one, as in plotting a survey it may often prevent considerable unnecessary labor.

10.—In using the Compasses, they should be held at the top between the forefinger and thumb, with one or more fingers under the hinge to increase or diminish the distance between the points gradually and without a jerk; in all cases the steel point should be guided by the finger of the other hand to the centre of the circle to be drawn, or to the line or scale to be measured. When several concentric circles are to be drawn, great care is requisite to avoid enlarging the centre hole. Persons unaccustomed to the use of compasses are very apt to turn them over and over in the same direction when spacing off a number of equal distances for the divisions of a scale. This necessitates a constant change of the hold by means of the finger and thumb, which often causes the point of the compass to be forced into the paper, or to be jerked off the point fixed all together. To obviate this, the points of the dividers should be worked alternately above and below the line along which the divisions are being set off; by this means the manipulation will be much more delicate, and there will be no liability of the compasses shifting.

To draw a straight line of any exact length required.—Use the marquois scale marked 50, until the use of diagonal scales is understood. On this scale will be found divisions down to $\frac{1}{50}$th of an inch, so that by expressing the length of any line in inches, and fiftieths of an inch, it can readily be measured off this scale with considerable accuracy. Thus, 3.15 inches $= 3\frac{15}{100} = 3\frac{7\frac{1}{2}}{50}$ and this can at once be measured off the 50 scale. The construction and use of marquois and diagonal scales are explained further on in this chapter.

To divide a given straight line into any required number of equal parts.—From one end of the line to be divided draw another line making with it an angle of about 20°. Set off on this line (with the dividers) equal parts to the number required, making them each *by estimation* nearly equal to one of the required divisions. Join the ends of the two lines, and through each of the points of division on the auxiliary line, draw lines parallel to this line. They will divide the given line into the required number of equal parts.

Example.—Draw AB 3.15 in. long, and divide it into 9 equal parts.

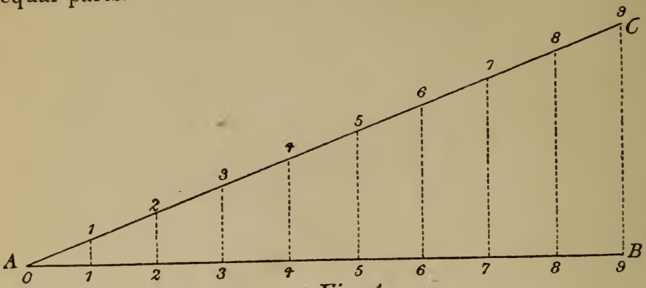


Fig. 4.

From A draw AC (of indefinite length), making an angle of about 20° with AB. Set off on AC, 9 equal parts, each nearly equal, by estimation to $\frac{1}{9}$th of AB. Join CB, and then through each point of division on AC, draw lines to AB parallel to CB. These lines will divide AB into 9 equal parts.

Note.—If the number of parts required happens to be a multiple of 2, then a simple and quick way of setting them off is to bisect the line, using the dividers. This can readily be done after one or two trials. Then divide each half again into halves, and each of the divisions so obtained again into halves, and so on, until the required number of parts is obtained.

We can now proceed to the actual construction, and explanation of different kinds of scales.

CONSTRUCTION OF SCALES.

In constructing any scale it must be borne in mind that—

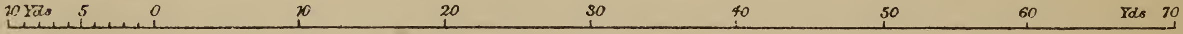
(*a*). It should be a line *about* 6 in. long.

(*b*). It must show complete divisions of units, tens, hundreds, or thousands, as the case may be.

It may be remarked here that a scale is not wrong because it is drawn more, or less, than 6 inches long. But

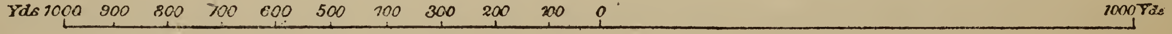
Plate I.

(Fig. 1.)



Scale of Yards 13 yds. to an inch. R.F $\frac{1}{468}$

(Fig. 2.)



Scale of Yards 5 inches to a mile R.F $\frac{1}{12672}$

(Fig 3.)

Scale of miles. R.F $\frac{1}{100,000}$

6 inches is a convenient and useful length, and therefore it is laid down as a guide to adhere to. Admitting this then, the first step invariably in constructing a scale is to decide *what is the number of units that will give a line about 6 inches long?* This being settled, the next step is to *find by a simple proportion sum the exact length of line that will represent the number of units fixed upon.*

A few examples will make this quite clear.

EXAMPLES IN PLAIN SCALES.

1. *Construct a scale of yards. R.F.* $\frac{1}{468}$.

Here the first thing to do is to decide how many yards will give a line about 6 inches long. We see at once from the R.F. that 468 inches, or 13 yards, are represented by 1 inch, therefore clearly 78 yards will go to 6 inches. But the scale must show complete divisions of (in this case) tens of yards.—*See ante* (*b*).—So we fix on 80 yds. as a suitable length, as it complies with this condition, and we know it will give a line *about* 6 inches long. Now we must find the *exact* length of the line required. The following proportion gives it:—

$$468 \text{ in.} : 80 \times 3 \times 12 \text{ in.} :: 1 \text{ in.} : x \text{ in.}$$

$$\text{from which } x = 6.15 \text{ inches.}$$

To draw the Scale.—Take a line 6·15 in. long, divide it into 8 equal parts: each will represent 10 yards. Divide the left part into 10 equal parts, each will represent 1 yard.—(*See Plate I., Fig.* 1).

2. *Construct a scale of* 5 *inches to a mile to measure yards.*—In this case it is clear that as 1760 yards are represented by 5 inches, 2000 yards will give us a line of *about* the usual length. Its exact length is found by the following proportion:—

$$1760 \text{ yds.} : 2000 \text{ yds.} :: 5 \text{ in.} : x \text{ in.}$$

$$\text{from which } x = 5.68 \text{ inches.}$$

To draw the Scale.—Take a line 5·68 in. long. Divide it into two equal parts: each will be 1,000 yards. Divide the left part into 10 equal parts, each will be 100 yards.

$\text{R.F.} = \frac{5 \text{ inches}}{1 \text{ mile}} = \frac{5}{1760 \times 3 \times 12} = \frac{1}{12672}$.—(*See Plate I., Fig.* 2.)

3.—*The R. F. of a German Map is marked* $\frac{1}{100000}$. *Construct a suitable English scale for it.*

The R.F. shows that 100000, inches or *roughly* $1\frac{1}{2}$ miles, are represented by 1 inch, therefore, evidently 9 miles will give a line *about* 6 inches long. The exact length is found in the usual way. Thus:—

$$100000\text{in.} : 9 \times 1760 \times 3 \times 12\text{in.} :: 1\text{in.} : x \text{ in.}$$
$$\text{from which } x = 5.70 \text{ ins.}$$

To draw the Scale.—Take a line 5.70ins. long: divide it into 9 equal parts, each will be one mile; divide the left part into eight equal parts, each will be 1 furlong. (*See Plate* I., *Fig.* 3.)

4.—*Construct a scale of* 8.75 *feet to an inch to show single feet.*

50 feet will give a line of a convenient length.

$$\text{Then } 8.75\text{ft.} : 50\text{ft.} :: 1\text{in.} : x \text{in.}$$
$$\text{from which } x = 5.71\text{in.}$$

To draw the Scale.—Take a line 5.71ins. long, divide it into 5 equal parts, each will be 10 feet; divide the left part into 10 equal parts, each will be 1 foot. (*See Fig.* 1, *Plate* II.)

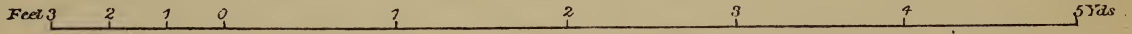
5.—*The line A B represents* 1000 *yards. Divide it properly, and mark its R.F.*

PLATE. II.

(Fig. 1)

Scale of feet R.F $\frac{1}{105}$

(Fig. 2)



Scale of Yards R F $\frac{1}{40}$

(Fig 3)

Scale of Paces R.F. $\frac{1}{2773.3}$.

AB measures exactly 3 inches, therefore—

$$\text{R.F.} = \frac{\text{3 inches.}}{\text{1000 yds.}} = \frac{3}{1000 \times 3 \times 12} = \frac{1}{12000.}$$

It should be divided, and figured, as below—

Scale of Yards. R.F. $\frac{1}{12000}$

(Fig 5.)

6.—*The R.F. of a map being* $\frac{1}{40}$, *construct a scale to show yards and feet.*

Here 6 or 7 yards will give a line of a suitable length.

Suppose we take 6 yards—

Then 40 inches : $6 \times 3 \times 12$ inches : : 1 inch : x inches
from which $x = 5.40$ inches.

To draw the Scale.—Take a line 5.4 inches long, divide it into 6 equal parts; each will be 1 yard; divide the left part into 3 equal parts; each will be 1 foot. (*See Plate II., Fig.* 2.)

7.—*Draw a Scale of Paces.—Take* 1 *pace* = 32 *inches, Scale*: 65 *paces to* $\frac{3}{4}$*ths of an inch.*

In this case it is easily seen that as 65 paces are represented by $\frac{3}{4}$ inch, 500 paces will give us a line of about 6 inches long, which is what we want. The proportion is then stated in the usual way—

65 paces : 500 paces : : $\frac{3}{4}$ inch : x inches,
from which $x = 5.76$ inches.

To draw the Scale.—Take a line 5.76 inches long, divide it into 5 equal parts; each will be 100 paces; divide the left part into 10 equal parts; each will be 10 paces. (*See Plate II., Fig.* 3.)

$$\text{R.F.} = \frac{\frac{3}{4}\text{ in.}}{\text{65 paces}} = \frac{3}{4 \times 65 \times 32} = \frac{1}{2773.\dot{3}}$$

8.—*The area of a map whose sides are* $25'' \times 30''$ *is* 30 *square miles.—What is the Scale of the Map?* In questions of this kind, we have only to state the area of the map in square inches, to be equal to the area of the ground in square yards, and take out the square root on both sides to get the answer; thus, in this case we have—

$$25 \times 30 \text{ sq. in.} = 30 \times 1760 \times 1760 \text{ sq. yds.}$$

The 30's cancel out, and we have left—

$$25 \text{ sq. in.} = 1760 \times 1760 \text{ sq. yds.},$$

and taking the square root on both sides, we get at once 5 in. = 1760 yds. or 1 mile, which is of course the answer.

9.—*Forty acres are represented by* 9 *sq. inches. Draw a scale of yards for the plan.* 1 *acre*=4840 *sq. yds.* Here 9 sq. in. $= 40 \times 4840 = 193600$ sq. yds. Taking the square root on both sides, we get—

$$3 \text{ inches} = 440 \text{ yds.}$$
$$\therefore 12 \text{ inches} = 1760 \text{ yds. or 1 mile.}$$
$$\therefore \text{R.F.} = \tfrac{1}{5280}$$

from which it can be seen that 900 yds. will give a line of the usual length.

Then, 5280 in. : $900 \times 3 \times 12$ in. :: 1 in. : x inches, or, 440 yds. : 900 yds. :: 3 in. : x inches, from which x = 6.13 inches.

To draw the Scale.—Take a line 6.13 in. long, divide it into 9 equal parts: each will be 100 yds., divide the left part into 10 equal parts, each will be 10 yds.

The following questions in plain scales should all be carefully worked out by the student, and some at all events of the scales, drawn and figured neatly, and accurately, as in the examples given :—

QUESTIONS FOR PRACTICE IN PLAIN SCALES.

1.—Construct a scale of yards R.F. $\frac{1}{10560}$.

2.—Construct a scale to measure yards, taking 3 inches to represent one mile: and give the R.F.

3.—Construct a suitable scale for a foreign map, on which is marked R.F. $\frac{1}{300000}$.

4.—Construct a scale of chains R.F. $\frac{1}{15840}$. 1 chain= 22 yards.

5.—R.F. being $\frac{1}{25}$, make a scale to show feet and inches.

6.—Two points are $10\frac{1}{2}$ miles distant from each other. On a map of the ground they are shown 5.25 inches apart. Give the R.F. and draw a scale showing miles and furlongs.

7.—2000 yards are measured—

(*a*) On a scale of 8 inches to a mile.

(*b*) On a scale of 3 miles to an inch.

(*c*) On a scale of 230 yards to an inch.

(*d*) On a scale of $1\frac{1}{2}$ inches to 8 chains.

Give the length in inches in each case, and the R.F. of each scale.

8.—Having lost your scale, you improvise one by dividing the edge of a visiting card into 8 equal parts, each to represent 100 yards, and using this improvised scale you execute your sketch. How will you ascertain the R.F. of the scale? Give an example.

9.—You make a sketch, scale $\frac{1}{10560}$. All your distances have been paced under the impression that you can pace yards exactly. But it is ascertained afterwards that it takes 120 of your paces to make 100 yards. Therefore $\frac{1}{10560}$ cannot be the correct R.F. of the sketch. What should it be? Explain.

10.—On a Russian map of Turkestan, of which the scale is 4.75 inches to 500 Versts, it is found that the distance from Kizil Arvat to Askhabad is 1.93 inches

What is the actual distance apart of these two places in miles. 1 Verst=1166.6 yards. Give the R.F. of the map.

11.—A map 18 in. × 8 in. represents 9 square miles. On what scale is it drawn?

12.—A square map whose sides are 3 inches long, represents a quarter square mile of country. Give its R.F.

13.—A map 18 in. long by $11\frac{1}{4}$ broad represents an area of $2\frac{1}{2}$ sq. miles. What is the scale?

COMPARATIVE SCALES.

Comparative scales are scales which have the same representative fraction, but which are differently graduated, thus one may be constructed to show yards, the other paces: and so forth.

The calculations for, and construction of, comparative scales are exactly the same in principle and method as in the case of plain scales: only, for purposes of comparison, two scales, or sometimes more, are generally shown instead of simply one. Thus, a French map may show a scale of metres, but to be generally useful to Englishmen it would be necessary to add to it a scale of yards with the same R.F. The two scales would be "comparative scales." Or, when about to make a military sketch, and anxious to avoid the frequent trouble of reducing numerous paced measurements to yards before plotting them, a comparative scale of paces is prepared, and used for the work, its R.F. being of course identical with the R.F. of the scale of yards at which it is proposed to execute the sketch.

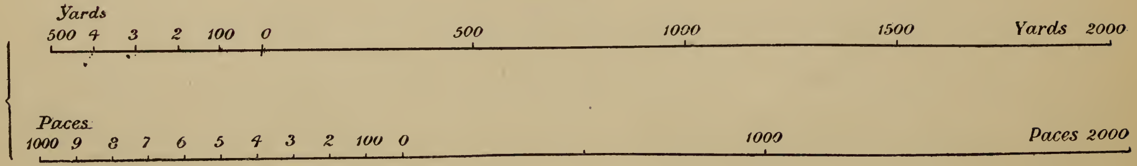
EXAMPLES IN COMPARATIVE SCALES.

1.—*Construct comparative scales for sketching, of yards, and paces. R.F.* $\frac{1}{15840}$. *Assume that a pace is equal to* 31 *inches.*

PLATE III

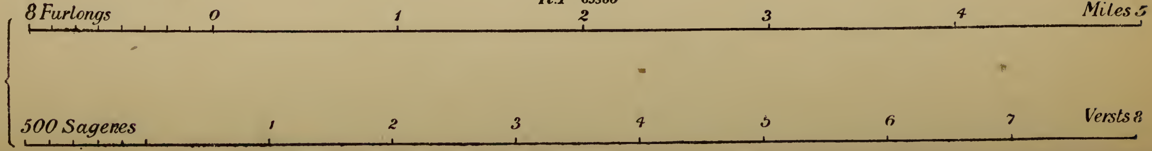
Comparative Scales of Yards and Paces

R F $\frac{1}{15840}$



Comparative Scales of Miles and Versts

R.F $\frac{1}{63360}$



First, make a scale of yards.

Take 2500 yards as a good length to show. Then from the following proportion—

$$15840 \text{ in.} : 2500 \times 3 \times 12 \text{ in.} :: 1 \text{ in.} : x \text{ in.}$$

We get 5.68 inches as the length of line representing this distance, and the scale would be drawn and figured as shown in *Plate* III., *Fig.* 1.

Now for the Scale of Paces. A pace is given as 31 in., rather less than a yard; so if we take, say, 3000 paces, we shall get a line of about the usual length. The following proportion will give it exactly—

$$15840 \text{ in.} : 3000 \times 31 \text{ in.} :: 1 \text{ in.} : x \text{ in.}$$

From which $x = 5.87$ inches, and the scale will be drawn, and figured, as shown in *Plate* III., *Fig.* 1.

2.—*Draw comparative scales of miles and Versts.* R.F. $\frac{1}{63360}$. *One Verst*=1166.6 *yards.*

First, take the miles. The scale is 1 inch to 1 mile exactly, therefore, 6 inches will represent 6 miles, and the scale will be drawn and figured as shown in *Plate* III., *Fig.* 2.

Now for the Versts. Knowing that 1 Verst=1166.6 yards, it is easy to find out from the R.F. that 1 in. represents approximately $1\frac{1}{2}$ Versts; therefore 9 Versts will give a line about 6 inches long. The exact length of it is found thus:—

$$63360 \text{ in.} : 9 \times 1166.6 \times 3 \times 12 \text{ in.} :: 1 \text{ in.} : x \text{ in.}$$

from which $x = 5.96$ inches, and the scale is drawn, and figured, as shown in *Plate* III., *Fig.* 2.

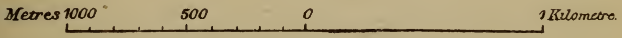


Fig. 6.

3.—*The above scale is drawn on a French map. Give its R.F. and draw a comparative scale of yards. 1 mètre being equal to* 39.4 *inches.*

The line given is measured, and found to be exactly $2\frac{1}{2}$ inches long, and it represents 2000 mètres, therefore the R.F. is—

$$\frac{2.5 \text{ inches}}{2000 \text{ mètres}} = \frac{2.5}{2000 \times 39.4} = \frac{1}{31520}$$

From this, it is evident 5000 yards will be a suitable length for our scale: and the following proportion gives the exact length of line representing this distance—

$$31520 \text{ in.} : 5000 \times 3 \times 12 \text{ in.} :: 1 \text{ in.} : x \text{ in.}$$

from which $x = 5.71$ inches, and the scale will be drawn and figured as shown in Plate IV. Fig. 1.

4.—*Construct comparative scales suitable for sketching on horseback, having ascertained that in a measured distance of* 300 *yards your horse takes* 120 *strides at a canter,* 270 *steps at a walk : and that in trotting that distance you rise in the saddle* 90 *times. R. F.* $\frac{1}{12000}$.

Here three scales at least are required, and a fourth to show yards would, of course, be added in practice.

First, take the strides, cantering.

We are told that 120 strides = 300 yds. ∴ 1 stride= $\frac{300}{120}$ yds.

Therefore 800 strides will be a proper number to take, and the following proportion gives the length of line which will represent them—

$$12000 \text{ in.} : 800 \times \tfrac{300}{120} \times 3 \times 12 \text{ in.} :: 1 \text{ in.} : x \text{ in.}$$

from which $x = 6$ inches exactly.

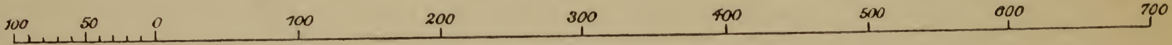
Note.—After considerable experience in teaching, I feel sure that at this stage a good many men will exclaim "Now where does that 800 come from ?" Once more, therefore, I would explain that it is found by comparing the proportion revealed by the R. F., with the proportion that a stride bears to a yard. This we know is as 120 to 300, or fractionally expressed, 1 stride $= \frac{300}{120}$ yards : and the R. F. tells us that 12000 inches, *i.e.* $333\frac{1}{3}$ yds., are represented by 1 inch, and therefore if we divide $333\frac{1}{3}$ by $\frac{300}{120}$ it will give us at once the number of *strides* that would be represented by 1 inch. But our line must be about 6 inches long, therefore multiplying the quotient by 6 will give us the right number to take. In this case, it happens to be exactly 800, but as has been previously explained, had it been something over, or under, 800, we should still have fixed on that number in order to facilitate the division. This explanation seems on paper to be long and roundabout, but in practice the actual process is simple and short, and can generally be done in the head ; only remember in every case when a scale has to be constructed, PLATE, IV

(Fig. 1)

Scale of Yards R. F. $\frac{1}{31520}$.

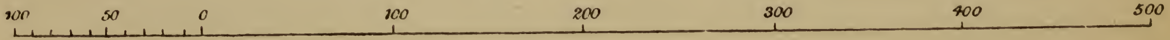
(Fig. 2)

Comparative Scales for Sketching on horseback. R. F. $\frac{1}{12000}$



Scale of Strides. at a canter

Scale of Steps, at a walk.



Scale of "Rises", at a trot

the first question always to ask and answer, is—"*How many of these————must I take to give me a line about* 6 *inches long?*" The answer will readily be found by reference to the R. F., which will always show how many of the units in question go to *one* inch.

We can now proceed to answer the rest of the question—

The scale of strides at a canter is disposed of—so we take next the steps at a walk.

We are told that 270 steps=300 yds. ∴ 1 step=$\frac{300}{270}$ yds.

Therefore 1800 steps will be the right number to take, (*see* explanatory note just given) and the length of line representing 1800 steps is found from the following proportion:—

$$12000 \text{ in.} : 1800 \times \tfrac{300}{270} \times 3 \times 12 \text{ in.} :: 1 \text{ in.} : x \text{ in.}$$

from which $x = 6$ inches exactly.

Finally for the "rises" at a trot.

90 rises = 300 yds. ∴ 1 rise = $\frac{300}{90}$ yards.

Therefore, 600 rises will be the right number to take, and the length of line representing is again exactly 6 inches, *vide* the following proportion:—

$$12000 \text{ in.} : 600 \times \tfrac{300}{90} \times 3 \times 12 \text{ in.} :: 1 \text{ in.} : x \text{ in.}$$

from which $x = 6$ inches exactly.

The scales would be all drawn, and figured, as shown in *Plate* IV., *Fig.* 2.

Often when making a rapid reconnoissance, the readiest way of estimating distances will be to note *the time* occupied in traversing them on horseback, and compare it with the animal's known rate of progression at a walk, trot, or canter, as the case may be. For example if you know your horse trots 10 miles an hour, and it takes you 10 minutes to trot from one village to another, you may put it down that those villages are 1⅔ miles apart. Distances ascertained in this way will, of course, be only approximate, but with a little care, and practice, work turned out by this method would be very fairly accurate; probably quite enough so for practical purposes. To save himself the trouble of constantly calculating the distances corresponding to the intervals of time noted, the sketcher would make comparative scales of distances and time before commencing work. This method is far better than the vexatious and laborious one of counting the horse's paces at a walk, trot, etc., which prevents the sketcher attentively studying the country and obtaining information for the report. For example:—

5.—Make comparative scales adapted to the paces of a horse that trots 9 *miles, and canters* 12 *miles an hour. Scale* 6 *inches to a mile.*

Here 3 scales are required. A scale of yards, and two scales of *time*, one for use when trotting, the other when cantering.

The scale of yards is calculated and constructed as usual. The horse trots 9 miles an hour, that is 264 yards in a minute: so we have only to measure off equal distances of 264 yds. (taken off the scale of 6 in. to a mile) along a line, and each of them will represent one minute; the left division may be subdivided to show seconds.

Exactly in the same way, it will be seen that 352 yds. per minute is the rate at a canter, and the scale of time for use at this pace is constructed in just the same way. (*See Plate V.*)

QUESTIONS FOR PRACTICE IN COMPARATIVE SCALES.

1.—Construct comparative scales of yards and paces. R.F. $\frac{1}{10000}$: 500 paces = a quarter of a mile.

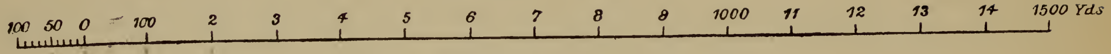
2.—Draw comparative scales of miles and versts. Scale 32 miles to an inch, 1 verst = 500 sagenes: 1 sagene = 3 archines: 1 archine = 28 English inches.

3.—Make comparative scales of chains and feet.—R.F. $\frac{1}{2560}$: 1 chain = 22 yards = 100 links.

4.—Construct comparative scales suitable for sketching on horseback. R.F. $\frac{1}{10560}$, having ascertained that in a

Comparative scales of distances & time,
for use on horseback.

R.F. $\frac{1}{10560}$.



Scale of Yards 6 Inches to a mile

Scale of time when trotting $\frac{1}{60}$

Scale of time when Cantering $\frac{1}{10560}$.

measured distance of 500 yards, your horse takes 450 steps at a walk, 180 strides at a canter, and that at a trot you have to rise in the saddle 140 times.

5.—Your horse trots 10 miles an hour, and canters 15; construct comparative time scales. R.F. $\frac{1}{15840}$.

6.—On a Turkish map is a scale of *Berris*. You find that 10 *Berris* are represented by a length of exactly 9 inches, and you know that 1 *Berri*=1823 yards.

Draw a comparative scale of English miles, and give the R.F.

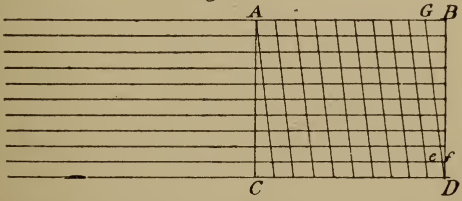
7.—Given that 1 German Schritt=2.4714 feet, and that 1 pace=30 inches, construct comparative scale of yards, paces, and Schritte. R.F. $\frac{1}{12500}$.

8.—A French map shows a distance of 300 metres, by a line 12 inches long. Draw a comparative scale of yards, and state the R.F. 1 metre=39.4 inches.

DIAGONAL SCALES.

Diagonal scales are scales diagonally sub-divided, to enable minute measurements to be taken from them. Measurements too small to be possible by direct division of a line Thus, suppose we require to measure off $\frac{1}{100}$th of an inch.

Fig.6.



We can do it by the diagonal arrangement, when clearly it is not possible to divide a line one inch long directly into one hundred equal parts. So we divide it into 10 parts, and then by the diagonal arrangement are able to get $\frac{1}{10}$th of one of these parts, which is of course the required $\frac{1}{100}$th of an inch. The principle of diagonal scales rests on the fact that in similar triangles the sides are proportional. This is evident from Fig. 6, which is constructed thus :—

Take AB one inch long. Divide it into 10 equal parts; each will be $\frac{1}{10}$th of an inch. Now under AB draw 10 parallel and equi-distant lines. From A and B drop perpendiculars AC and BD to the bottom line, and then divide CD also into 10 equal parts. Now join the divisions on the top and bottom lines diagonally, and the scale is completed, and the smallest division on it is EF, which is $\frac{1}{100}$th of an inch. For it is clear from the construction that GBD and EFD are similar triangles; therefore their sides are proportional, and therefore

$$EF : GB : : FD : BD,$$

but FD is by construction $\frac{1}{10}$th of BD, therefore EF is $\frac{1}{10}$th of GB. But GB is $\frac{1}{10}$th of an inch, therefore EF must be $\frac{1}{10}$th of $\frac{1}{10}$th of an inch, that is $\frac{1}{100}$th of an inch.

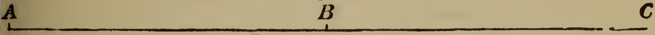
In this case it will be observed that the original, or primary divisions are 1 inch. By sub-division we get smaller divisions of $\frac{1}{10}$th of an inch each, and by the diagonal arrangement we can get down to $\frac{1}{100}$th of an inch, which decimally expressed is .01 of an inch, and this is the smallest measurement which can be taken off a diagonal scale when the primary divisions are one inch.

Now suppose the primary divisions to be only *half an inch* each, all the rest of the construction being exactly the same. Then it is clear that the smaller divisions on the top and bottom line, being each $\frac{1}{10}$th of *half* an inch, must be each $\frac{1}{20}$ of an inch, and the diagonal arrangement enabling us to read $\frac{1}{10}$th of $\frac{1}{20}$th of an inch, the smallest reading possible is $\frac{1}{200}$th of an inch, or decimally expressed, .005 of an inch.

Similarly, if the primary divisions had only been *a quarter of an inch* each, then the smaller ones would have been $\frac{1}{10}$th of $\frac{1}{4}$ of an inch, that is $\frac{1}{40}$th of an inch each, and the smallest possible reading off the diagonal scale would have been $\frac{1}{10}$th of $\frac{1}{40}$th of an inch, that is $\frac{1}{400}$th of an inch; or decimally put, .0025 of an inch.

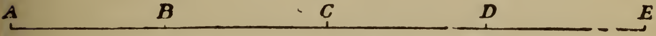
Few of the protractors supplied with boxes of mathematical instruments show a diagonal scale of inches. Most of them have a diagonal scale of ½ inches and ¼ inches. Therefore, to mark off by their aid a line of any given length, the simplest way is to take the given measurement directly off the scale, and lay it off twice, or four times, according to which scale you use. Thus, using the ½ inch diagonal scale, draw a line exactly 3.42 inches long. Take 3.42 directly off the scale in the dividers, and lay it off from A to B, and then again, by turning the compasses over, from B to C. The line A C is 3.42 inches long, and is bisected in B.

Fig. 7.



If only a ¼ inch diagonal scale had been available for the operation, the measurement taken off it would have been laid off *four* times, viz., from A to B, B to C, C to D, and D to E, and the resulting line A E would as before have been exactly 3.42 inches.

Fig. 8.



One or two examples will now be given to illustrate the method of constructing diagonal scales, and figuring them, and using them.

1. *Draw a scale of inches showing hundredths diagonally.*— The rule in all these cases is to resolve the number to which the divisions are to be extended into two factors. Then divide the given length (here it is one inch) into as many equal parts as there are units in one factor, and take as many parts on the vertical line as there are units in the other factor. Thus, in this case, the divisions of 1 inch are to be extended to 100. 10 × 10 = 100, and are the factors required. Therefore to make the scale, we take a line 6 inches long, divide it into 6 equal parts ; each of course will be 1 inch. Divide the left part into 10 equal parts. Draw 10 lines under the original line, equi-distant from each other and parallel to it. Through each inch division drop perpendicular to the bottom line. Divide the left bottom division into 10 equal parts, and join the top and bottom

small divisions diagonally. The scale is made, and must be figured as shown in *Fig.* 1, *Plate* VI. Let it be noted that the primary divisions are inches, the smaller ones read horizontally are *tenths* of an inch, and that the vertical readings are *hundredths* of an inch.

To use the Scale.—Suppose it is required to measure off 3.54 inches. This is 3 inches + $\frac{5}{10}$ths + $\frac{4}{100}$ths ; so we have only to remember that the tenths must be measured off the bottom *horizontal* line, and the hundredths off the *vertical line*, and we get it at once by placing one point of the compasses where the 5 on the bottom line and the 4 on the vertical line meet, and the other point on the 3-inch division. —(*See Fig.* 1., *Plate VI*).

2.—*Construct a Scale of miles. Scale 50 miles to an inch, to show single miles diagonally.*

Here the two factors making 50 are 10 and 5. We take a line 6 inches long, and divide it into 6 equal parts, each of which will represent 50 miles. The left of these is then divided into 5 equal parts, each of which is 10 miles. Then the parallel horizontal lines (10 in number) are drawn, and the scale completed as in the previous example, and figured as shown in *Fig.* 1, *Plate* VII. It is clear that the primary divisions read 50 miles each, the smaller ones 10 miles each, and the vertical ones single miles from one up to ten. Suppose it is required to measure 187 miles off the scale; we should take 150 miles off the primary divisions, 30 off the smaller ones, and 7 miles off the vertical ones. The total distance would be from × to × (*Fig. 2, Plate VI.*)

3.—*Draw a Scale to show yards, feet, and diagonally, inches. R.F.* $\frac{1}{72}$.

The R.F. being $\frac{1}{72}$ the scale is 6 feet, or 2 yards to an inch. Take a line 6 inches long, divide it into 12 equal parts, each will be 1 yard. Divide the left part into 3 equal parts, each will be 1 foot. Then by using 12 parallel lines, we get a reading of $\frac{1}{12}$th of 1 foot, that is 1 inch. The scale is figured as shown *Fig. 1, Plate VII.*

4.—*Draw a diagonal Scale to show miles and furlongs, R.F.* $\frac{1}{190080}$.

PLATE VI

DIAGONAL SCALES

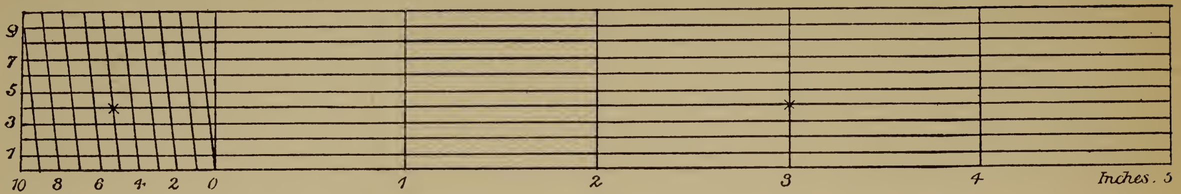


Fig. 1. Diagonal Scale of Inches.

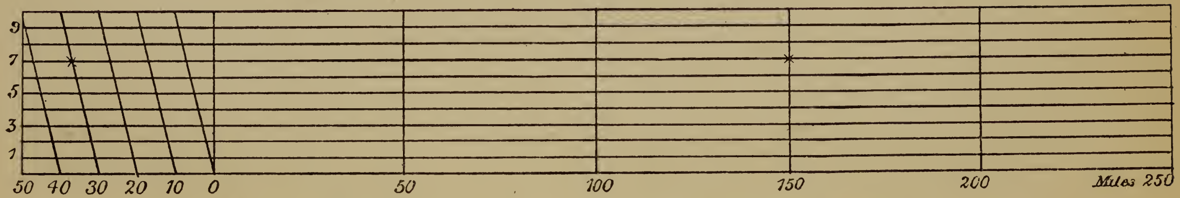


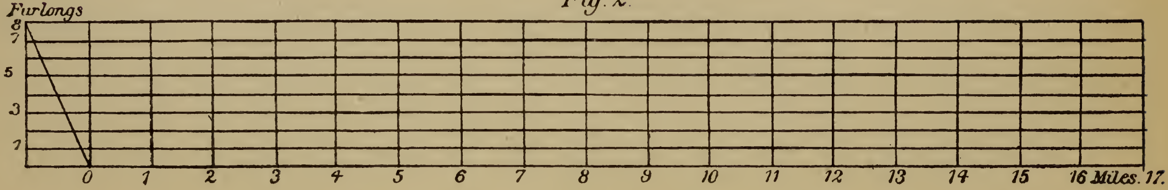
Fig. 2. Scale of miles. 50 miles to an inch $\frac{1}{3168000}$.

DIAGONAL SCALES –

Fig. 1.

Diagonal scale of yards, feet & inches. $\frac{1}{72}$.

Fig. 2.



Diagonal Scale of miles & furlongs $\frac{1}{190080}$

PLATE VIII.

VERNIER SCALES

Fig. 1

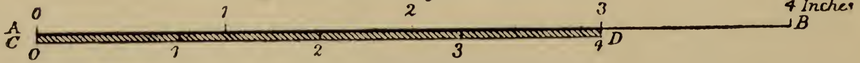


Fig. 2

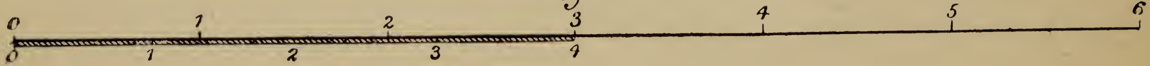


Fig. 3

Fig. 4

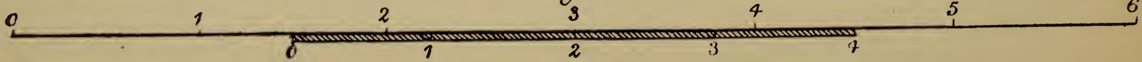
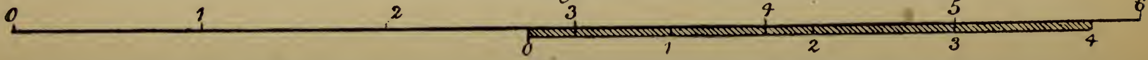


Fig. 5



Here if 18 miles be taken, it will be found that it is represented by a line exactly 6 inches long. Divide it into 18 equal parts, each of 1 mile. Draw 8 lines underneath it, because a furlong is $\frac{1}{8}$th of a mile, and complete, and figure the scale, as shown in *Fig. 2*, *Plate VII.*

QUESTIONS FOR PRACTICE IN DIAGONAL SCALES.

1.—Draw a scale of yards, R.F. $\frac{1}{216}$, and show single feet diagonally.

2.—Draw a scale of yards, R.F. $\frac{1}{21120}$, and show divisions of 10 yards diagonally.

3.—Draw a scale of chains, showing down to 10 links diagonally. Scale—4 inches to a mile. 100 links = 1 chain = 22 yards.

4.—Construct a diagonal scale to show the one-thousandth of a foot, full size.

5.—Construct a scale of paces, showing single paces diagonally. Scale—12 inches to a mile.

6.—Construct a scale of 120 miles to an inch, to show single miles diagonally, and give the R.F.

VERNIER SCALES.

A Vernier is an arrangement by which a very minute measurement can be taken off a scale. Verniers may be moveable, or fixed. They are generally moveable when used with surveying instruments, and fixed when used with plain scales. The principle of their construction is the same in either case, and is best illustrated by examples.

Let A B (*Fig.* 1, *Pl. VIII.*) be a line four inches long, divided into four equal parts: each, therefore, is one inch. Take C D equal to three of these parts, and divide it also into four equal parts. Then each part on C D is smaller on each part on A B by $\frac{1}{4}$th, and C D is a Vernier reading to $\frac{1}{4}$th of an inch. The two scales should be numbered as shown with their zeros coinciding. To use the scale, remember that the Vernier reads quarters of inches, and the original scale whole inches, and that *the difference* between one of the Vernier divisions, and one of the original divisions is $\frac{1}{4}$ of an inch: and therefore, of course the difference between *two* of the Vernier divisions and two of the original divisions is $\frac{2}{4}$th of an inch, and so on. Suppose then we want to take off the scale $2\frac{1}{4}$ inches. Place one point of the compasses on the 1 of the Vernier to get the $\frac{1}{4}$ inch (from the 1 on the Vernier to the one on the original scale is obviously $\frac{1}{4}$ of an inch) and then count on two whole inches on the original scale. This brings us to the 3, and there we place the other point of the compasses.

The foregoing example illustrates the whole principle of the Vernier, and should be thoroughly mastered, and understood before proceeding further.

If in this example C D was a sliding Vernier, its construction would be just the same, but its zero would be marked with an arrow-head. The whole inches would be read as before off the top line, that number nearest the arrow *to its left* being taken: and the quarters would be read off the Vernier, that number being taken which is found nearest to the arrow coinciding exactly with one of the top divisions. To make this scale clear, see the diagrams given in *Plate* VIII.

In *Fig.* 2 the arrow points to zero, therefore the reading is 0.

In *Fig.* 3 the Vernier has been moved forward until 1 on the Vernier coincides exactly with 1 on the original scale. The reading, therefore, is $0\frac{1}{4}$ inches.

In *Fig.* 4 the Vernier has been moved forward until the 2 on the Vernier coincides exactly with 3 on the original scale, and the reading now is 1 inch (the number nearest to the arrow on its left) and $\frac{2}{4}$ths, *i.e.*, $1\frac{1}{2}$ inches.

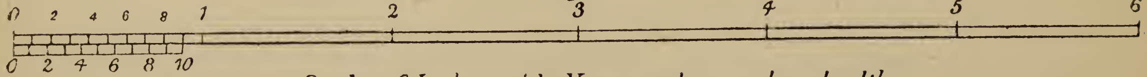
In *Fig.* 5 the Vernier has been moved still further forward, and the reading is $2\frac{3}{4}$ inches.

Example 2.—*Construct a Vernier to read hundredths on a scale of inches.*

Take a line six inches long, divide it into six equal parts of 1 inch each. Divide the left part into 10 equal parts:

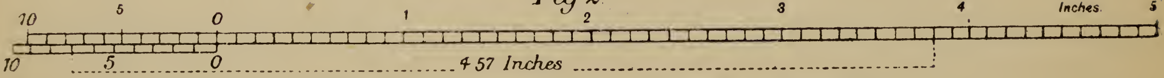
VERNIER SCALES

Fig 1.



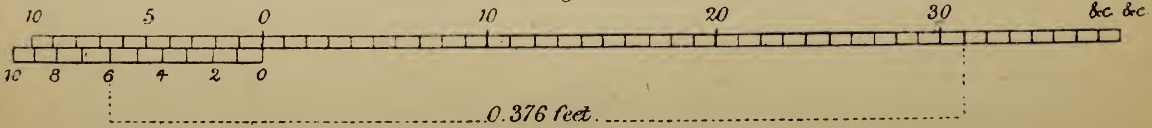
Scale of Inches with Vernier showing hundredths

Fig 2.



Scale of Inches with Vernier showing hundredths

Fig 3.



Scale with Vernier grading to $\frac{1}{1000}$th of a foot each will be $\frac{1}{10}$th of an inch. Now for the Vernier. Take a line equal to nine of these parts, and divide it into ten equal parts. Then each Vernier division is smaller than one of the original (tenth of an inch) divisions by $\frac{1}{10}$th; that is, *the difference* between one of the original divisions and one of the Vernier divisions is $\frac{1}{10}$th of $\frac{1}{10}$th of an inch, *i.e.*, $\frac{1}{100}$th of an inch, and thus a Vernier is made that reads to $\frac{1}{100}$th of an inch. *See Fig.* 1, *Plate* IX. for the method of drawing and figuring the scale.

To use the Scale.—Remember that the large divisions are whole inches, the smaller ones *tenths* of inches, and that the Vernier reads *hundredths* of inches. Now suppose we require to measure off 4.57 inches. This is 4 inches + $\frac{5}{10}$ths + $\frac{7}{100}$ths. The $4\frac{5}{10}$ths can be taken off the top line at once; and the $\frac{7}{100}$ths will be the distance from 7 on the Vernier to 7 on the scale of tenths. These two measurements together will give exactly 4.57 inches.

Now it is obvious that this is a very clumsy way of taking off a measurement; therefore, to make it simple, and avoid all unnecessary shifting about of the compasses in the operation, it is usual to divide the original line *throughout its length* into tenths, (or whatever size may be necessary) and to take for the Vernier one part *more*, instead of one less, than the number of Vernier divisions required. Thus, in the preceding example. Take a line six inches long, divide it throughout its length into tenths of an inch. For the Vernier take a line equal to eleven of these parts, and divide it into ten equal parts. Then evidently each Vernier division is greater than one of the original divisions by $\frac{1}{100}$th of an inch. The scale is drawn and figured as in *Fig.* 2 *Plate* IX. Now to take 4.57 inches off it is a simpler matter far than before, and it can be done at one operation. Place one point of the compasses on the seven of the Vernier. From this to the zero is $\frac{7}{10}$ths + $\frac{7}{100}$ths, *i.e.*, .77 Substract .77 from 4.57, and 3.8 or $3\frac{8}{10}$ths remain, and the other leg of the compasses must, therefore, be extended until it reaches $3\frac{8}{10}$ths beyond the zero.

Example 3.—*Draw a Vernier to read to the one-thousandth of a foot.*

Take a line one foot long. Divide it into 100 equal parts. For the Vernier take a length equal to eleven of these parts, and divide it with ten equal parts. Then each of these Vernier divisions being $\frac{1}{10}$th larger than one of the primary divisions, it is evident that *the difference* between them is $\frac{1}{1000}$th of a foot. Draw and figure the scale as in *Plate IX., Fig. 3.*

To use the Scale.—Remember that the primary divisions are *hundredths* of a foot, and that the Vernier reads *thousandths.* For example, measure off 0.376 of a foot. This is $\frac{37}{100}$ths and $\frac{6}{1000}$ths. Place one point of the compasses on the 6 of the Vernier, from this to the zero is $\frac{6}{100}$ths and $\frac{6}{1000}$ths, *i.e.*, .066. Subtract this from .376 and it leaves .31, or $\frac{31}{100}$ths, to be measured off the top scale. *(See Fig. 3. Plate 9.)*

Example 4.—*Draw a scale of 12 feet to an inch, and attach a Vernier to it, to read single inches.*

Take a line 6 inches long, divide it into 72 equal parts; each will be a foot. For the Vernier, take 13 of these parts, divide it into 12 equal parts; then each of the Vernier divisions will be $\frac{1}{12}$th larger than one of the original divisions. In other words, each Vernier division is $1\frac{1}{12}$th foot, or 1 foot 1 inch; and 2 of the Vernier divisions are 2 feet 2 inches; 3 of them, 3 feet 3 inches, and so on. The scale should be numbered as shown in *Fig. 1. Pl. X.*

To use the Scale.—Suppose it is required to take off 35 feet 9 inches; put one point of the compasses on the 9 of the Vernier, and the other on the 26 of the scale of feet. This will be the correct distance; for from Zero to the 9 on the Vernier is 9 feet 9 inches, and this subtracted from 35 feet 9 inches, leaves 26 feet to be measured off the scale of feet.

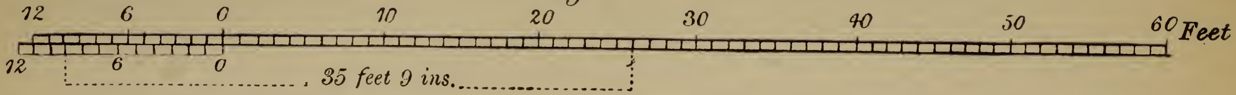
Example 5.—*Make a Scale of 8 inches to a mile to read to 20 paces, and add a Vernier to read to 5 paces.*

Take 1500 paces as a convenient length for the scale; then

PLATE X.

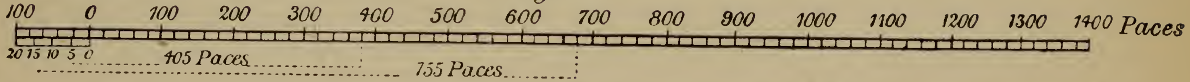
VERNIER SCALES

Fig. 1



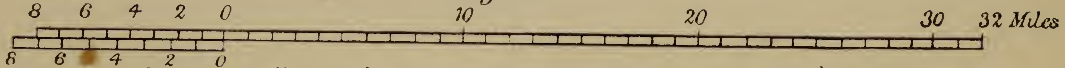
Scale of feet, with Vernier showing Inches. R.F. $\frac{1}{144}$

Fig 2



Scale of paces with Vernier to 5 paces R,F $\frac{1}{7920}$

Fig. 3.



Scale of miles with Vernier showing furlongs R.F $\frac{1}{506880}$

the following proportion will give the exact length of line representing 1500 paces—

$$\frac{1760 \times 3 \times 12}{30} : 1500 :: 8 \text{ in.} : x \text{ in.}$$

from which we get $x = 5.68$ inches.

Therefore, take a line 5.68 inches long, divide it into 15 equal parts; each will represent a hundred paces: further, divide each part into 5 equal parts, and each of them will be 20 paces. Then for the Vernier, take a length equal to 5 of these parts, and divide it into 4 equal parts. Each of these will be $\frac{1}{4}$th larger than one of the original divisions. In other words, each will be $20 + \frac{1}{4}$ of 20, that is 25 paces; and, therefore, as *the difference* between one of the original divisions and one of the Vernier divisions is 5 paces, we have a Vernier reading to 5 paces.

The scale should be drawn, and figured, as shown in *Fig 2, Pl. X.*

To use the Scale.—Remember that the difference between one of the original divisions and one of the Vernier divisions is 5 paces; between 2 of them, 10 paces; between 3 of them 15 paces, and so on. The original divisions are 20 paces each, therefore it is clear that any number of even divisions of 20, can be taken directly off the original scale, but any surplus must come off the Vernier. Thus, if the distance required is 405 paces, it would be 20 of the big divisions, and the bit between, 1 on the original scale, and 1 on the Vernier *(See Fig. 2, Pl. X).* If it were 755, it would be 37 big divisions and 15 paces; the bit between, 3 on the original scale, and 3 on the Vernier.

EXAMPLE 6.—*Draw a Scale of miles, R.F.* $\frac{1}{506880}$ *and attach a Vernier showing furlongs.*

The scale is 8 miles to an inch, therefore, 40 miles will be represented by a line exactly 5 inches long. Divide this line into 40 equal parts, each will be 1 mile. For the Vernier, take a length equal to 9 of these parts, and divide it into 8 equal parts; each will be $\frac{1}{8}$th larger than one of the original divisions. In other words, each Vernier division is $1\frac{1}{8}$th miles, that is 1 mile and 1 furlong, and thus a Vernier is made reading furlongs *(Vide Pl. X., Fig. 3).*

Example 7.—*Construct a Vernier for a sextant to read to half minutes.*

The arc of the sextant must be divided into *thirds* of degrees (20 minutes each). For the Vernier, take a length equal to 39 of these, and divide it into 40 equal parts; each will be $\frac{1}{40}$th less than one of the arc divisions. In other words, the difference between one of the Vernier divisions and one of the arc divisions is $\frac{1}{40}$ of 20 minutes; that is half a minute; and thus the Vernier gives reading down to half a minute, or 30 seconds.

To read off the angle (See Plate XI.)—For the degrees take the number nearest to the arrow of the Vernier on its left. In *Fig.* 1 it is 31°. Then for the minutes, see which Vernier division coincides exactly with one of the arc divisions: here it is 15. Therefore, the complete reading is 31° 15′.

Observe that if the arrow has passed any of the 20 minute divisions on the arc, 20 minutes must be added for each one passed to the number of minutes recorded by the Vernier. Thus, in *Fig.* 2, *Plate* XI., the reading is 31° 40′, *plus* the Vernier reading which is 13′, therefore the complete reading is 31° 53′.

Note.—The student should procure a Sextant, and setting it at various angles practice himself in reading them off until he can do it with facility. Some pocket-sextants are graduated to read to half minutes, but the majority to minutes only. Nautical sextants are ordinarily constructed to read to 10 seconds.

QUESTIONS FOR PRACTICE.

1.—Construct a Vernier to read *fiftieths* on a scale of inches.

2.—Construct a scale of yards R.F. $\frac{1}{21120}$ and attach a Vernier giving readings to 10 yards.

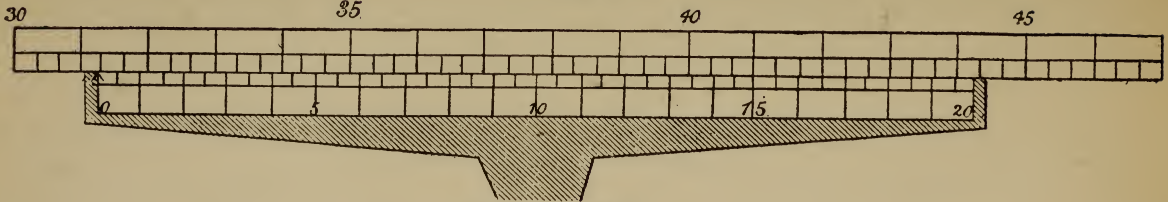
3.—Construct a scale of feet, R.F. $\frac{1}{20}$, and attach a Vernier reading inches.

PLATE XI

SEXTANT. VERNIERS

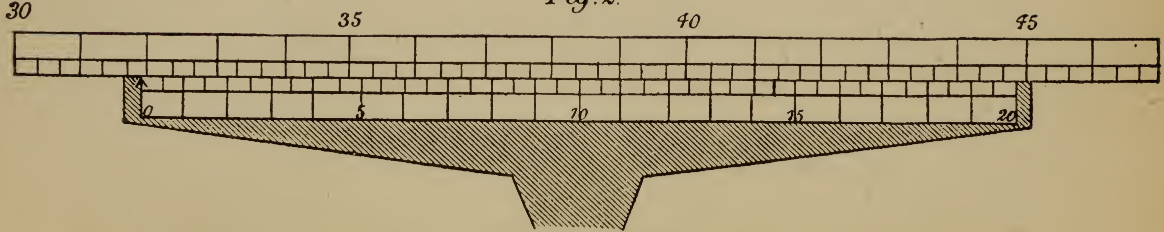
Reading to half a minute.

Fig. 1.



Reading 31°15'

Fig. 2.



Reading 31°53

4.—Construct a Vernier to read one minute on the arc of a Sextant. Make ten degrees of the arc two inches long.

5.—The arc of a Sextant is graduated to 15′. The Vernier shows 60 equal divisions. To what degree of accuracy does it read?

6.—Explain the construction of the Vernier attached to an Abney's Level, on which the smallest reading is 10′.

7.—Explain the construction of a Vernier reading to ten seconds.

8.—On a Vernier attached to a Barometer, 25 divisions are found to be equal to 26 divisions of the scale, each of the latter being equal to .05 of an inch. To what degree of accuracy does the Vernier read?

In connection with scales, it will be useful to note the following measures:

100 Links = 1 Chain.
1 Chain = 22 Yards.
80 Chains = 1 Mile.
10 Square Chains or 4840 Sq. Yds. = 1 Acre.
220 Yards = 1 Furlong.
8 Furlongs = 1 Mile.
1 Mètre = 39.37 Inches.
1 Schritt = 29.65 Inches.
1 Archine = 28 Inches.
1 Verst = 1166.6 Yards.

THE MARQUOIS SCALES.

A set of Marquois scales consists of two flat rectangular rulers, each one foot long, and a right-angled triangle of which the hypotenuse, or longest side, is three times longer than the perpendicular, or shortest side. The rulers have scales on them marked 20, 25, 30, 35, 40, 45, 50, and 60. Each scale is doubly divided. The inner rows of divisions, those along the centre of the ruler, form in each case what are called *the natural scales*, and on these natural scales it will be found that *one inch* is divided into the actual number of parts marked, and *also* into parts ten times their size. Thus, on the scale marked 30, you will find on the natural scale that 30 of the smallest divisions, or three of the large ones, make exactly one inch.

The outer rows of divisions, those along the edge of each ruler, form what are called *the artificial scales.* On these each division is equal to three of the corresponding small divisions on the natural scales. This is so arranged in order that the proportion between the scales may be the same as the proportion between the hypotenuse and the shortest side of the triangle. This being so, it is evident that by placing the triangle above one of the rulers, and sliding it up and down as required, any number of parallel lines can be ruled at any given distance apart from each other, with great exactness. Thus, suppose it is required to rule two lines exactly $\frac{7}{30}$ths of an inch apart, we have only to place the triangle on the ruler marked 30, rule a line, then slide the triangle over 7 of the divisions on the outer, or artificial scale, and rule another line, when it will be found that the distance apart of the two lines is exactly 7 of the corresponding small divisions of the inner, or natural scale of 30, that is $\frac{7}{30}$ths of an inch.

The proposition that whatever distance the triangle is moved along the ruler, it only descends *vertically* one-third of that distance, may be proved thus :— *(See Plate XII.)*

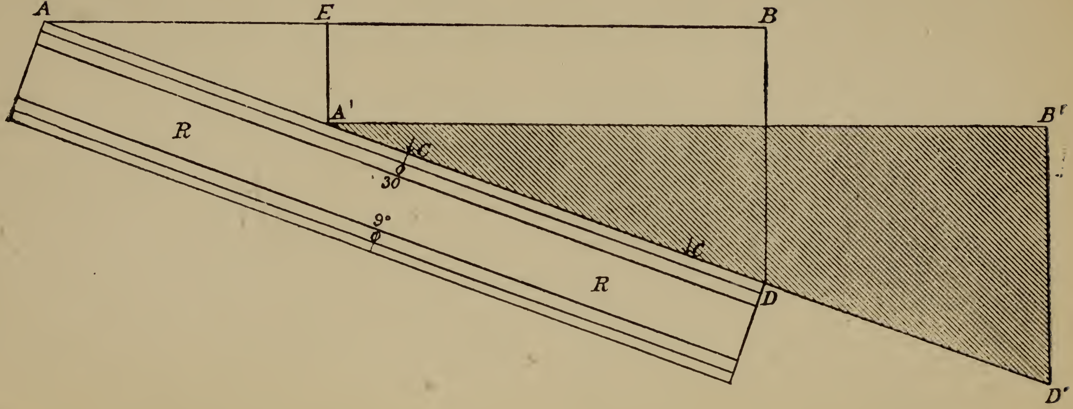
Let A B D be the position of the triangle on the ruler R, the arrow C of the triangle coinciding with O the centre of the ruler. Now slide the ruler down to the position A′ B′ D′, and draw A′ E parallel to D B. Then evidently A E A′ and A B D are similar triangles, and therefore E A′ : A′ A : : B D : D A.

But B D is $\frac{1}{3}$rd of D A by construction, therefore E A′ is $\frac{1}{3}$rd of A′ A : and as A′ A (from point to point of the triangles) is equal to C′ C, (from arrow to arrow on the triangles) therefore E A′—the vertical distance descended—is $\frac{1}{3}$rd of C′ C—the distance that the triangle has moved along the ruler. Q.E.D.

In other words, if C′ C were (say) 20 divisions on any one of the outer or artificial scales, then E A′ would be exactly

PLATE XII.

THE MARQUOIS SCALES



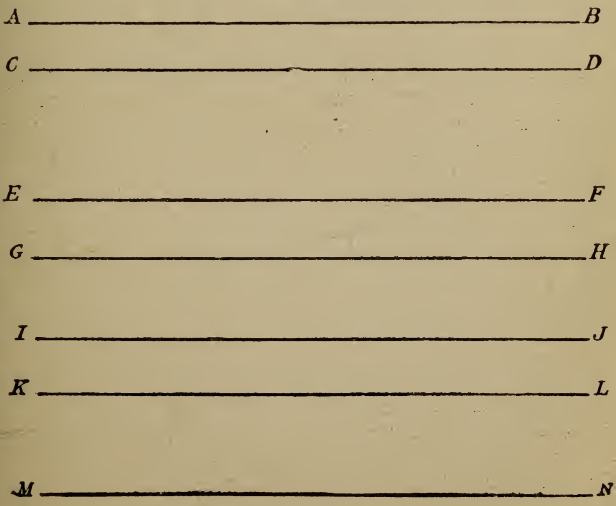
20 divisions on the corresponding inner, or natural scale.

Example.—Using the marquois scales, draw parallel lines $\frac{1}{4}$, $\frac{5}{7}$, $\frac{5}{16}$, $\frac{4}{9}$, $\frac{3}{10}$, and $\frac{8}{15}$ths of an inch apart.

Each fraction must first be reduced to one with a denominator the same as one of the scales marked on the rulers. Thus :—

$\frac{1}{4}=\frac{10}{40}$: $\frac{5}{7}=\frac{25}{35}$: $\frac{5}{16}=\frac{2\frac{1}{2}}{8}=\frac{12\frac{1}{2}}{40}$: $\frac{4}{9}=\frac{20}{45}$: $\frac{3}{10}=\frac{9}{30}$: and $\frac{8}{15}=\frac{16}{30}$. Now rule a line A B, place the triangle just touching it, then using the scale of 40, slide down 10 divisions, and rule the line C D. C D is parallel to A B, and distant from it $\frac{10}{40}$ths, or $\frac{1}{4}$th of an inch. Now substitute the 35 scale for the 40 scale, slide the triangle down 25 of its divisions, and rule the line E F. E F is parallel to C D, and distant from it $\frac{25}{35}$ths, or $\frac{5}{7}$ths of an inch. In the same way the remaining lines are drawn.

Fig. 9.



FURTHER USES OF THE MARQUOIS SCALES

The following notes will be found useful:—

1.—The scales to which profiles and plans of fieldworks and details of fortification are usually drawn, are nearly always to be found on the marquois scales. Thus, ordinary scales for such drawings are—

$\frac{1}{48}$, or 4 feet to an inch.
$\frac{1}{60}$, or 5 ,, ,,
$\frac{1}{72}$, or 6 ,, ,,
$\frac{1}{120}$, or 10 ,, ,,
&c., &c.

These are all to be found on the marquois scales, therefore no time need ever be wasted in calculating, or drawing them.

2.—It is useful to note that if the small divisions on any natural scale be taken to be *feet*, then the corresponding divisions on the artificial scale will be *yards*, the two scales being to each other in the proportion of 1 to 3. For example: A bastioned front is to be drawn on a scale of $\frac{1}{600}$ or 50 feet to an inch. Some of the measurements will be required in feet, and some in yards; but they can all be taken off the marquois scale of 50, the feet being measured off the natural scale, and the yards off the artificial scale.

3.—The marquois rulers are each a foot long. It may sometimes be required to divide a foot into a given number of equal parts, and then it will be useful to remember that by multiplying the number marked on the ruler by .4, 1.2, or 4, you will ascertain the number of equal divisions in a foot marked on that scale, and one of them may be just what you want. For example: On what scale will you find a foot divided into 100 equal parts? On the 25 scale, because $25 \times 4 = 100$. Again, on the scale of 20, into how many equal parts is one foot divided? Into 8, 24, and 80: because $20 \times .4 = 8$, $20 \times 1.2 = 24$, and $20 \times 4 = 80$.

CHAPTER II.

COPYING, REDUCING, AND ENLARGING MAPS.

There are various ways of making a copy of a map for Military purposes. The most common methods are briefly described and compared below.

1.—A Copy may be made on Tracing Cloth.—Lay a piece of tracing cloth over the original, glazed side up; pin it at the four corners: then trace off at once, using a crow-quill and Indian ink. Writing ink won't do: it runs: and pencil does not mark on tracing cloth. Any colouring that may be necessary is left to the very last, and then the paint is laid on the *back* of the tracing cloth, and the colour will show through. Work with a wet brush and lay on the colour rather darker than you want it to appear from the front.

This method of making a copy is clean, quick, and accurate, and the original is not injured or defaced. Moreover, if interrupted before the tracing is finished, the copy can at any subsequent time be again put down in its exact position, and the work resumed. Another advantage of using tracing cloth is that the copy is durable, and can be folded and carried in the pocket without injury.

Tracing Paper.—The same method as tracing cloth, but it is not so durable. The paper is apt to crack when folded.

2.—A copy can be made by "Pricking Through."—The original is laid on the sheet of paper on which the copy is to be made, and secured at the corners. Then with a needle, or pin, the position of the chief points is pricked through. The original is then removed, and the details lightly filled in by eye with a pencil. Next any necessary painting is done, and finally the whole map is inked in.

This method is fairly accurate, but it requires much more time and care than No. 1. The original is more or less damaged by the pricking process: and there is the obvious disadvantage that if the work be interrupted in the middle, it is not easy to place the original a second time in its exact place over the copy, unless marks have been made very carefully at the sides, or corners of the paper.

3.—A Copy can be made by using Carbonic Paper.—Lay a piece of Carbonic paper on a sheet of clean paper, and then the map that is to be copied on the top of all, face uppermost. Pin all three together at the corners. Then with a fine, but blunt-pointed instrument, go carefully over all the features to be copied, leaning evenly, and rather heavily on it. On removing the Carbonic paper, an outline of the map will be found on the clean paper below. This must be touched up, painted, and then inked in, &c., as before.

This method is tedious, and not very clean. It is not recommended. It has in a greater degree than No. 2 the disadvantage that great difficulty is experienced in re-finding your place if once disturbed in the middle of your work; and the original is certain to be more or less damaged by pressing on it with a pointed instrument. This can, however, be avoided, by first taking a copy of the original in pencil on tracing *paper*, and afterwards working from this copy, and not from the original. But of course this adds considerably to the time and trouble.

4.—A Copy can be made by using Squares.—Rule the original into squares of any convenient size,* and rule a sheet of paper for the copy into squares of the same size. Then fill in by eye, square by square. This method is a fairly good one, and would be the one generally resorted to when Tracing Cloth is not available: but when it is, then method No. 1 is certainly the most simple, expeditious, and practical.

To Reduce, or Enlarge a map to any given scale.—The most practical methods for military purposes are the *system of squares* and by means of a pantograph.

Using Squares.—If a copy is required of a map twice the size of the original, it is evident that if the original be ruled into *one-inch* squares,* and the paper for the copy into the same number of *two-inch* squares, and then the map copied

---

* To avoid damaging, or defacing the original, by ruling it with squares, a sheet of glass may be laid on it, and the squares ruled on the glass.

carefully square by square, the result will be a correct copy twice the size of the original.

Similarly, if a copy were required half the size of the original, we might rule the original into *one-inch* squares as before; but the paper for the copy into *half-inch* squares; or the original might, if more convenient, be ruled into *two-inch* squares, and the paper for the copy into *one-inch* squares. The result would of course be the same.

Consequently we get this simple rule: *The sizes of the squares must be in the same proportion as the scales of the maps*, Then to apply this rule to any case, we have only to decide arbitrarily upon any convenient sized squares for the original, and calculate the correct size of the squares for the copy by a comparison between the given scales. A few examples will make this quite clear.

1. *A map is drawn on a scale of 4 inches to a mile: a copy is required on a scale of 6 inches to a mile. How will you arrange the squares?*

Answer.—I rule the original into one inch squares. I see the squares for the copy must be larger, in the proportion that 6 inches to a mile is a larger scale than 4 inches to a mile: and I calculate their exact size from the following proportion:—

$$4 : 6 :: \text{1-inch squares} : x \text{ inch squares},$$
$$\text{from which } x = 1\tfrac{1}{2} \text{ inches.}$$

2.—*The scale of a map is* $\frac{1}{10560}$. *A copy is wanted on a scale of* $\frac{1}{12672}$. *Explain how you will make it?*

Answer.—In this case, the copy is to be on a smaller scale than the original. I decide on *two-inch* squares for the original, and I calculate the size of the squares for the copy, thus—

$$\frac{1}{10560} : \frac{1}{12672} :: \text{2-inch squares} : x \text{ inch squares},$$
$$\text{from which } x = 1\tfrac{2}{3} \text{ inches.}$$

3.—*On a French plan it is found that* 4·5 *inches* = 700 *metres. A copy is wanted on a scale of* 6 *inches to a mile.*

1 *metre* = 1·0936 *yards. The original being ruled into one-inch squares, what will be the size of the squares for the copy?*

Answer.—In this case we have only to write down the representative fractions of the two maps, and then we shall see at once which is the larger of the two, and know how to proceed.

The R.F. of the French map is $\frac{4.5 \text{ inches}}{700 \text{ metres}} =$

$$\frac{4.5}{700 \times 1.0936 \times 36} = \frac{1}{6124.1}.$$

The R.F. of the copy is $\frac{6 \text{ inches}}{1 \text{ mile}} = \frac{6}{1760 \times 36} = \frac{1}{10560}.$

Clearly therefore the copy is to be on a smaller scale than the original, and therefore the proportion stated below will give the correct answer:—

$\frac{1}{6124.1} : \frac{1}{10560}$ :: 1-inch squares : x inch squares,

from which $x = 0.579$ inches.

The *Pantograph* is a simple instrument for enlarging and reducing drawings. These instruments are made in various sizes and full directions for using given with each. With a 5/- pantograph carefully manipulated, quite accurate work can be turned out. Before starting work always test the accuracy of setting the instrument, and again before finishing.

The following is a good plan to enlarge or reduce a bit of ground which has small depth.

XYZ is a bit of road and it is required to reduce it to $\frac{1}{3}$ its linear length.

Well outside it take a point W and join W X, W Z, and any other points such as W Y.

Make W X′, W Z′ $\frac{1}{3}$ of W X and W Z. Draw X′ R parallel to X R and Z′ S′ parallel to Z S. The intersection of X′ Z′ and W Y gives Y′. (*Fig.* 9*a*).

Having sufficient points fill in by eye.

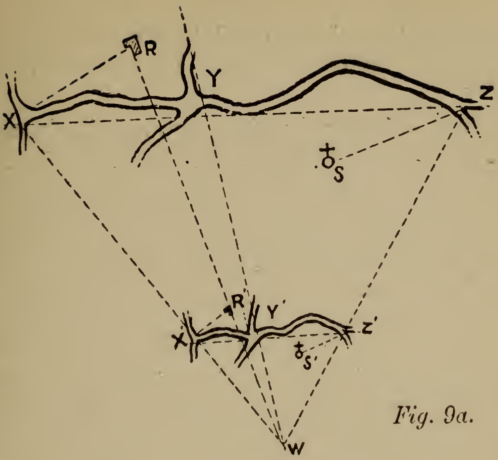


Fig. 9a.

QUESTIONS FOR PRACTICE.

1.—A map is drawn on a scale of $\frac{1}{31680}$: a copy is required on a scale of $\frac{1}{12672}$. Explain how you would proceed?

2.—The scale of a Russian map is 5.88 inches to 7 versts. A copy is wanted on a scale of 2 inches to a mile. The squares for *the copy* are to be one inch. What will be the size of the squares for the original? 1 verst = 3500 feet.

3.—A hasty sketch of a position was made with an improvised scale, on which it is afterwards found that 1000 yards were represented by 3.75 inches. A fair copy is now required on a scale of $\frac{1}{10560}$. Explain how you would make it?

4.—A plan, the R.F. of which is $\frac{1}{6000}$, is to be copied at R.F. $\frac{1}{23000}$. The original has one-inch squares drawn on it. What will be the size of the squares for the copy?

5.—The R.F. of a plan is $\frac{1}{12500}$. A copy is required on a scale of 4 inches to a mile. The exact length of the original plan is 20 inches. What will be the exact length of the copy?

6.—A map is to be enlarged from a scale of $\frac{1}{2500}$ to a scale of 8 feet to $\frac{1}{8}$th of an inch. What sized squares will you use?

7.—Compare briefly the advantages and disadvantages of some of the methods of copying maps that you are acquainted with.

CHAPTER III.

DEFINITIONS.

The following definitions should be well studied, and learnt by heart. They will be constantly referred to throughout the succeeding chapters of this book.

Part I.—*(To be read in connection with Chapters I. to VII.)*

A Military Survey is a Survey made for Military purposes by Officers of special attainments, and with instruments of precision, such as the Theodolite, or Sextant. The object in view would be great accuracy rather than great speed.

A Military Sketch is a sketch of ground, showing all important tactical features such as any officer should be able to make using only Prismatic Compass or Plane Table, or even without instruments. In this case time is a more important element than *extreme* accuracy.

**Triangulation, or Intersection*, is the process of accurately fixing the position of important points on the area to be surveyed, by means of a measured base, and intersections of bearings, or angles.

Well conditioned Triangles are those which give good inter sections, *i.e.*, neither too acute, or too obtuse.

Base, or Base-line, is a carefully-chosen and accurately measured

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*The term "Triangulation" is specially applicable to *survey*, not *sketching*, operations, where all the figures resulting from the observations made are perfect triangles. This is not the case in rapid military sketching, where the work therefore is more correctly described as "Intersection."

line, which is the starting-point of a survey, and upon which the accuracy of the triangulation chiefly depends.

Bearing.—The magnetic bearing of an object is the number of degrees between a line drawn to it from the point of observation, and the magnetic meridian passing through that point. The annexed diagram makes this clear. O being the point of observation, the bearing of A is 40°; of B, 110°; of C, 245°; and of D, 312°. It will be observed that the degrees must be counted from North, round by East, South and West, up to North again.

The true bearings of OA, OB, OC, etc., are the angles which these lines make with a true meridian (true North and South line) running through the point O.

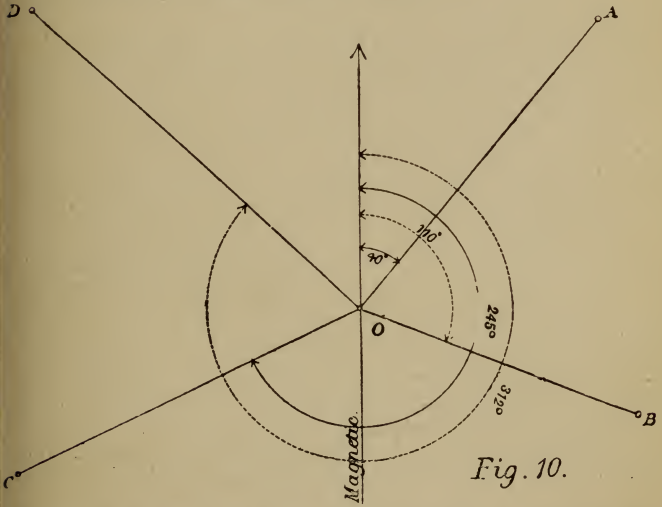


Fig. 10.

A *Ray* is a term used when Plane-tabling to express the direction of an object. When working a Plane table it is incorrect to speak of "bearings;" (though it is constantly done) we should say "rays" instead. A magnetic bearing is the direction of an object *with reference to the magnetic meridian of the point of observation,* whereas a ray is the simple direction of an object, without any reference to the points of the compass.

Meridian or *Meridian-line* is a TRUE North and South line.

Magnetic Meridian, is a MAGNETIC North and South line, the direction of which rarely coincides with the direction of *true* North and South.

Magnetic Meridians are magnetic North and South lines drawn at irregular intervals over the sketching paper, to enable the bearings observed with the Prismatic Compass to be correctly protracted.

NOTE.—There is often, even in books on the subject, a good deal of confusion caused by indifferent use of the terms "meridians," "meridian lines," &c., whether *magnetic* North and South lines, or *true* North and South lines, are being spoken of. It will save much perplexity to the student if he will make it a rule always to say "*magnetic* meridians," if he means Magnetic North and South lines; and "*true* meridians" if he alludes to true, or geographical North and South lines.

Plotting is the process of transferring to paper the observation recorded in a Field-book, or the bearings taken with a compass.

A Field-book is simply a pocket-book in which a Surveyor records in a particular form, observations made in the field, and distances measured, &c. These observations are subsequently "plotted" at leisure.

A Traverse is the process of sketching roads, rivers, &c., by taking forward bearings, or angles, pacing or chaining along them, and measuring or judging offsets to objects on either side. Whenever practicable, a traverse should start from a point fixed by triangulation, and close on a similar point.

An Offset is a measurement made to an object at right angles to the forward direction. In Military Sketching offsets are more often judged than actually measured.

Secondary Offsets are measurements perpendicular to the principal offsets. They would only be used when some outline has to be put in with great accuracy, thus :—

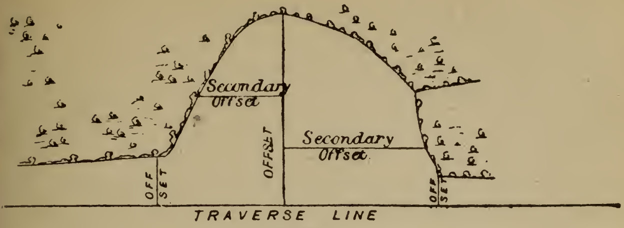


Fig. 11.

A *Station* is a point fixed by the triangulation: or, speaking generally, it is any point fixed by the intersection of two or more bearings, or angles; or by pacing, or chaining (as in a traverse). Stations should always be clearly marked on a sketch by a small circle, and bearings to or from them should not penetrate its circumference.

A *Station-line* (in a traverse) is the direct line between any two Stations: the one in fact which the Surveyor walks along as he measures from one station to the next.

A *Forward-angle* (in a traverse) is the forward direction, or bearing, from one station to the next in succession.

A *Back-angle* (in a traverse) is the direction, or bearing, of the last station passed.

Back-angle traversing consists in fixing each fresh forward direction by reference to the last back-angle. This is the ordinary method of traversing with the Theodolite: and in working with a Plane table, or when making an eye-sketch, each fresh forward direction is usually plotted with reference to the last one. In eye-sketching, or if traversing with a sextant, (which might be done, but would be work quite unsuited to a sextant) this method *must* be pursued.

A *Closing angle* (in a traverse) is the bearing taken, when the work is completed, to some fixed point, (a triangulated station if possible) to see if the traverse "closes" satisfactorily. If it does, this bearing on being plotted should pass exactly through the station concerned, and the actual distance from the spot where the bearing was taken to the Station observed, should correspond with the distance between these points on paper.

The Zero-line of a sketch is the one upon which all the others depend for the accuracy of *their direction.* If working with a prismatic compass each bearing taken is quite independent of any other observations, and is plotted solely with reference to Magnetic North; therefore, in this case, a Magnetic North and South line would be the zero-line of the sketch. But if working with a pocket sextant, or if plane tabling independently of a compass, or when making an eye-sketch, each fresh angle or bearing must be taken and plotted with reference to one that has preceded it, and therefore in these instances, *the first line plotted* becomes the zero-line of the sketch.

PART II.—(*Not to be read until Chapters I. to VII. are finished*).

A Hill is irregular high ground from which the ground falls away in every direction.

A Ridge is the summit of a hill, which is narrow and long.

A Plateau.—The summit of a hill, if it is fairly level, and of some extent, is called a *plateau.*

A Saddle is a *col.* It is a depression between two adjacent hills, or in the middle of a ridge, or a neck, or depression connecting an underfeature with the main hill, or with a spur.

A Spur is a feature, generally ridge-shaped, running out and down from the main hill.

A Knoll, or *hillock*, or *underfeature*, is a small hill connected with the main hill, or with a spur, by *a saddle or col.*

Watershed is the high ground, the hill, or range of hills, in which streams and rivers take their rise. The ground from which water flows in two different directions.

Watercourse is the lowest part of a hollow, or valley, or ravine, or bed, in which water would flow.

All the before described features are shown in *Plate* XIII. The main watershed line is indicated by a chain-dot line, and a few of the minor ones by dotted lines. Some of the underfeatures are marked with a cross, and some cols with the letter C. The streams are shown in blue. There is a saddle or col just where the W of "Watershed" comes, and there is another between the letters E and D of the same word. The student will find it worth his while to study this bit of ground carefully, and after a while, when Chapters VIII. and IX. have been mastered, to try and design other pieces in the same style, introducing the different features according to fancy, or to suit particular conditions.

A Contour is the line of intersection of a hill by a horizontal plane: or is an imaginary line, or mark, running completely round a hill, at the same level all the way round. Approximate contours are used in military sketching, *i.e.*, contours determined as accurately as can be, with such instruments as clinometer, abney level, aneroid barometer

Form Lines.—Are approximate contours sketched in by eye, and showing the general shape of the ground rather than the altitude.

Orthogonals.—Are imaginary lines drawn down a slope, cutting each contour in succession at right angles. An orthogonal frequently, but not necessarily, coincides with the watershed line of a hill, or spur; and is generally the line selected to pace down when the contours are being sketched in.

Vertical Intervals—generally written V.I., and ALWAYS *expressed in feet*—are the vertical distance that one contour is above or below another. The vertical intervals are fixed as follows for sketches drawn on a scale of 2 inches to a mile and under:—

$$\text{V.I. (in feet)} = \frac{50}{\text{No. of inches to a mile (of the scale of map).}}$$

For larger scales officers should use their discretion: thus V.I. for map 4 inches to 1 mile is $12\frac{1}{2}$ feet. This is inconvenient so use 10, 15 or 20, preferably 10 or 20, as 1 inch ordnance maps show contours at 100 V.I., which would be useful if an enlargement were made.

Horizontal Equivalent—generally written H.E., and ALWAYS *expressed in yards*—means literally the number of yards measured horizontally which correspond to any given degree of slope, the V.I. being fixed. For example, you ascend a slope of 5° until you are 20 feet vertically above your starting point. You will find then that your horizontal distance from your starting point is 76.4 yards. In other words, the H.E. of 5° (the V.I. being 20 feet) is 76.4 yards. (*See Fig.* 12.)

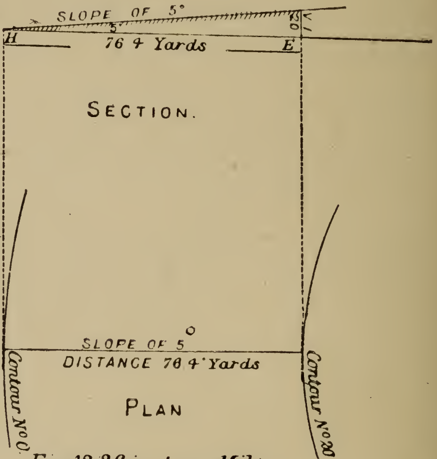


Fig 12. 36 in to a Mile.

This distance can either be calculated from a formula which will be found and explained in its proper place (Chapter VIII.) or ascertained by construction; that is by drawing a figure to scale, as in the annexed diagram, and afterwards measuring off the base, or H.E. If done carefully, the result ought to be the same as by calculation. But the scale must always be an exaggerated one. In the illustration appended, 36 inches to a mile has been used. Looking at this illustration, it is evident that the following definitions of horizontal equivalent are correct. *Horizontal equivalent is the distance in plan between any two contours.* (*See Plan, Fig.* 12) or, *is the base of a right-angled triangle, of which the perpendicular is the V.I. (in feet) and the angle opposite to it is the slope of the hill.* (*See Section, Fig.* 12.)

A Gradient is a slope expressed by a fraction, which also


PLATE XIII
WATERSHED
Ridge
Plateau
C
C
C
C
C
120
105
90
75
60
45
45
60
60
45
45
60
60
60
60
45
60
75
90
90
90
105
120
130
120
105
90
75
75
75
60
45
30
15

indicates its steepness; or to put it more definitely, which shows the ratio between the vertical height, and the horizontal base of the slope. The numerator of the fraction (which should always be 1) represents the height, and the denominator the base. Thus, if we speak of a gradient of $\frac{1}{6}$, or 1 in 6, we mean that the height of the slope is one-sixth of its base: *e.g.*, if the base was 1200 yards, its height would be 200 yards, or 600 feet.

A slope may be, and often is expressed in degrees. Thus a slope may be referred to as a slope of $\frac{1}{12}$ (1 in 12) or a slope of 5°. If the degrees only are given, the corresponding gradient can at once be found (approximately only, but with sufficient accuracy for all practical purposes) by dividing the given degrees by 60. Thus, a slope of 5° is the same thing as a gradient of $\frac{5}{60}$ or $\frac{1}{12}$: a slope of 12° would be $\frac{12}{60}$ or 1 in 5, and so on. This is particularly to be remembered, as it will be found very useful later on. Of course, conversely, if the fraction expressing a gradient be multiplied by 60, the corresponding degree of slope is at once ascertained. Thus, the gradient being $\frac{1}{15}$, the corresponding slope would be $\frac{1}{15} \times 60 = 4°$, and so on.

A Section (of ground) is a representation of the outline that would be exposed by its intersection with a vertical plane in any given direction.

Section Lines are horizontal parallel lines by means of which sections are drawn. Each line represents a rise, or fall, of one contour. The name is also applied to the lines which are selected to pace along when contours are being sketched in. (*See Chap.* XI., *p.* 175).

A Datum, or *Datum-line*, or *level*, or *point*, is an assumed level with reference to which heights are measured, or compared, or shown in a section. It is usually, but not necessarily, the lowest point in a sketch.

Hachures are the strokes of the pen, or pencil, either horizontal or vertical, with which the shading of hills may be effected. Vertical hachuring is used on many English and foreign small scale maps. An illustration of this is given in Plate XIII.

Stumping is the process of developing hill-features by shading them in mezzo-tint, using a leather stump and black lead pencil. It is now seldom used.

Brushwork is a method of developing hill features by washes of neutral tint or sepia, laid on in the usual way with a paint brush, light or deep washes being used according to the degree of slope represented. It is very effective if cleverly done, but it requires special aptitude, and practice.

The *Layer* system of showing hills is an excellent method. Bartholomew's half-inch tourists' maps show it very plainly.

Orientation is the term applied to the practice of setting a map or plane table so that the north line points north.

CHAPTER IV.

CONVENTIONAL SIGNS.

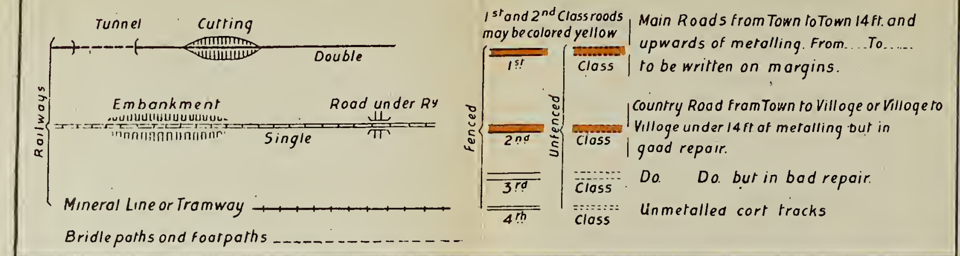
Conventional signs are particular ways of representing on a sketch natural features and objects, such as roads, railways, telegraphs, troops, &c. These signs have been found to be the most suitable ones that can be devised, and therefore one should be familiar with them, and invariably use them in a military sketch.

Plates XIV., XV., and XVI., show all the authorised conventional signs used in Military Sketching. They should be attentively studied, together with the explanatory remarks below. The symbols used on the Ordnance Survey Maps are given for *information only.*

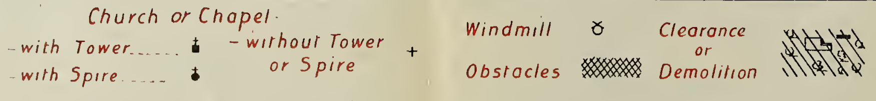
(*a.*) Roads should be drawn with continuous lines if they are fenced, or have any obstructions along their sides, which may interfere with troops moving freely on and off them. If no such obstructions exist, they are drawn with dotted lines. It should be written along them here and there, whether they are metalled or unmetalled ; occasionally

CONVENTIONAL SIGNS & TERMS USED IN MILITARY TOPOGRAPHY.

SYMBOLS USED ON ORDNANCE SURVEY MAPS (for information only)



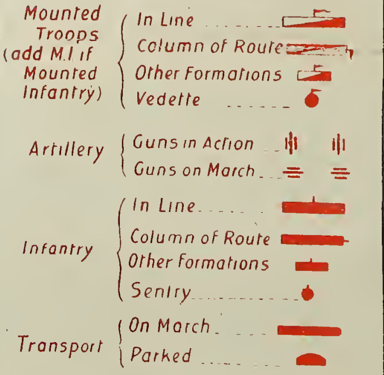
CONVENTIONAL METHODS OF SHEWING OBJECTS IN NATURE



ABBREVIATIONS

Post Office	P
Post & Telegraph Office	T.
Sign Post	S.P.
Well	W

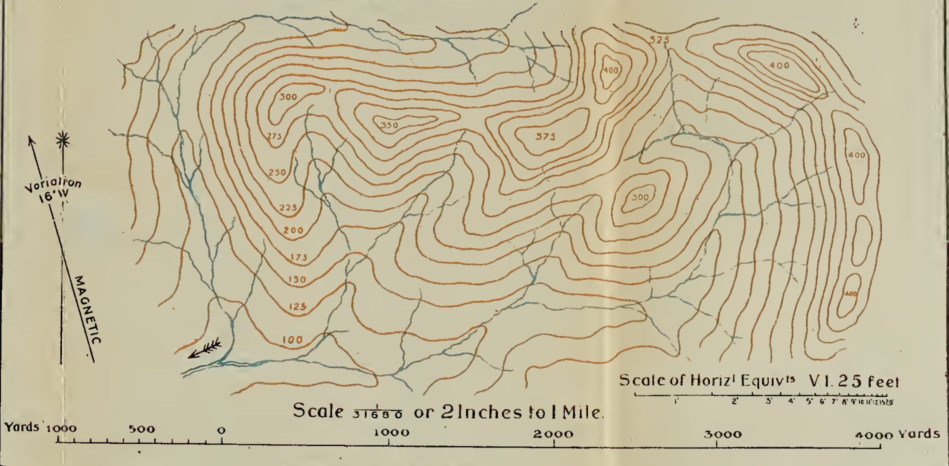
BRITISH TROOPS



British Troops Red Opposing Forces Blue

REPRESENTATION OF HILL-FEATURES AND CONVENTIONAL COLOURS.

Colours. Contours and heights. burnt sienna: where this is not available, or time does not allow, contours may be shewn by chain-dotted black lines. Streams, blue (or black): double line when over 15 ft wide. Roads, outlined in black metalled roads may be colored brown. Woods, to be shewn by symbols for trees or colored green. Villages, and houses, black.



SYMBOLS USED IN FIELD SKETCHING

Note Words which should appear on the Sketch are shewn in black

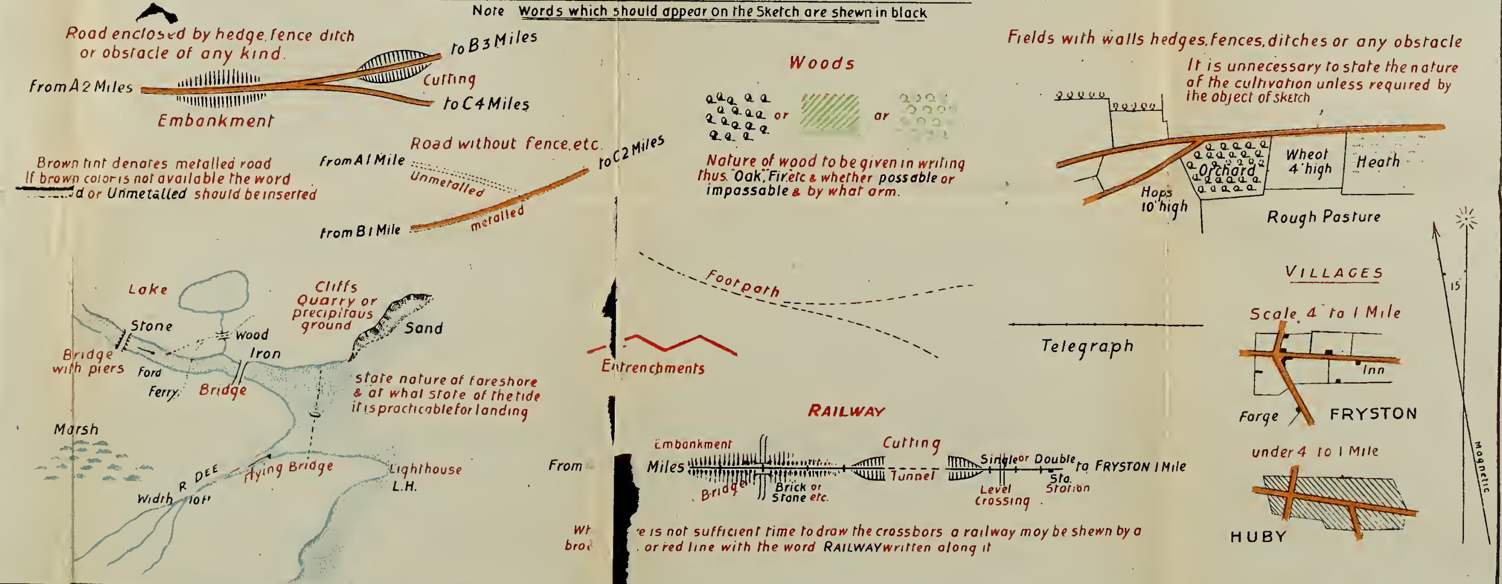


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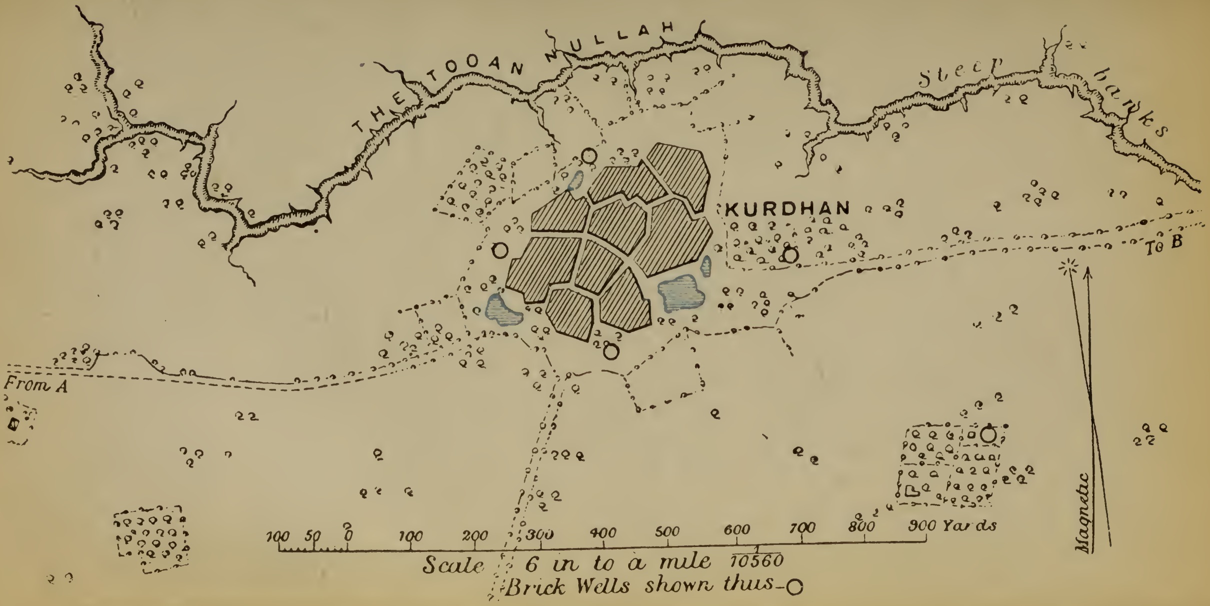
Plate XV.

INDIAN VILLAGE NULLAH &c



the width of metalling should be written along the road, thus, 12′m. means a metalled road 12 feet wide. Every road or railway shown on a sketch, should have *From*—— at one end of it, and *To* —— at the other. As a general rule *From*——should be used on the left, and at the bottom of a sketch ; and *To*—— where the road leaves the sketch, at the top, or on the right hand side of the paper. If it is known, the distance in miles to the next town or village should be added, thus :—*To FRIMLEY, 21 miles ; or To HYTHE, said to be 16 miles.*

(*b*) A railway is shown by a continuous black line with cross bars, or by a single red line. When time does not admit, by a single black line and the word " railway " written along it. The word "single," or "double" should be written in a similar manner.

(*c*) The name of a river should be written winding along, and in its course, and the direction of the current shown by an arrow in mid-stream. Only a river or stream that flows all the year round should be coloured. Rivers over 15 feet wide are shown by double lines under 15 feet by a single line.

The bank nearest the left hand top corner of sketch, should be slightly thickened.

(*d*) The construction of a bridge should be indicated by the words *iron*, *stone*, *wood*, *boats*, *&c.*, as the case may be.

(*e*) It should be noted in regard to woods what the timber is, and whether there is undergrowth hindering the passage of troops, or not. As a rule, pine and beech woods are free from undergrowth.

(*f*) Villages are generally one of three types :—1, circular ; 2, long in proportion to their breadth ; or 3, broad in proportion to their length. In drawing them their general shape should be depicted accurately. It may be a matter of some importance.

Indian villages are simply an agglomeration of mud huts, with numerous narrow tortuous and ill-defined paths leading through them. They should be drawn as shown in *Plate* XV.

On small scales the villages should be blocked in ; on larger scales the houses and gardens should be shown.

(*g.*) A marsh is shown by horizontal lines, blue if colour is used, and a few short black vertical strokes to represent the rushes.

(*h.*) A heath is shown by small vertical strokes, short at the ends and longer in the middle, but the bottom edge kept quite horizontal.

A heath and marsh are very apt to be mistaken for one another, it is therefore advisable to write the word *heath* or *marsh* over it.

(*i.*) In drawing an "embankment" and "cutting" care must be taken to draw the hachures at right angles to the road, &c. In an embankment the hachures are drawn from the road, and in a cutting towards the road. A fine line is drawn along the top of a cutting.

(*j.*) A "cliff" and "quarry" require care in drawing. The top of a cliff is not straight but indented; draw a few vertical lines to represent the salients and re-entrants, *i.e.*, spurs and ridges, then put in a few cross bars from the salients meeting in the re-entrants, thick and close together near the top, getting thinner and farther apart as they near the bottom.

(*k.*) Postal Telegraph Offices are shown by the letters P.T.O.; forges and smithies by the letter F; important public-houses by P.H.

(*l*) When troops are shown on a sketch, the symbols need not be drawn to scale. The unit and strength can be written alongside.

In outpost sketches the letters P.S.R. stand for the words picquet, support and reserve. The direction a patrol takes should be shown by an arrow.

Intrenchments are shown by a single line on scales up to 4 inches to a mile, and on scale of 4 inches to a mile and over by a double line.

(*m.*) All printing should be horizontal with a few obvious exceptions, *e.g.*, the names of rivers, roads, railways, mountain ranges, and any description of nature and condition of a track of ground, which should be written as far as possible to extend over the ground described.

The names of towns, villages, rivers, on a sketch or in a report should be in plain black capitals thus :—WOOLWICH. The size does not matter so long as the letters are neatly drawn. For headings $\frac{10}{60}''$ and for other printing, capitals $\frac{7}{60}''$, small letters $\frac{4}{60}''$ is suggested as a useful size.

(*n*) Finally, do not trust entirely to conventional signs to convey your meaning, if you think there is the smallest chance of their not being understood. For instance, the conventional signs for a marsh and heath. Again, you reconnoitre several miles of road. The country on one hand you find to be a network of fields with hedges and ditches ; and on the other fairly open and flat, but somewhat wooded. Now instead of covering your paper on one side with the conventional sign for hedge rows, &c., and on the other with trees, it would be decidedly better to write on the one side :—"*Fields all along here, with hedges and ditches impassable for troops*" *:* and on the other—"*Country here open and flat, ground firm and practicable for all arms, but somewhat wooded, and view much interfered with.*"

In sketching on small scales, the following is the principal detail to be shown :—

Roads, milestones, telegraph and telephone lines, rivers, streams, canals, railways, bridges, villages in block, only showing the main roads passing through them, farms, solitary houses, woods, orchards, lakes, ponds, marshes, post and telegraph offices, forges, smithies, wells.

COLOURS.

Sketches should always be coloured if there is time, and if the materials are available. In the field coloured chalks can be substituted for paint. The Germans use them largely for rapid sketching. They help to give a clear and vivid idea of details.

When paint is used it must be laid on *before* the sketch is touched with ink. Pencil lines too should be first rubbed out, unless it is intended to ink them in eventually.

If tracing cloth is used for the fair copy of a field sketch, the paint is the *last* thing put on, and then it is all put on the reverse side, and rather darker than intended to appear on the front.

The conventional colours for various objects are as follows :—

Contours and Heights.—Brown or red, or if these colours are not available, by a chain dotted black line.

Streams, Lakes and Ponds.—Blue wash. Only streams which run all the year should be painted ; otherwise they should be drawn in black. The edges are a deeper shade of the same colour, and the bank nearest the top left hand corner, from where the light is supposed to come, being in shade a little thicker still.

Roads.—Outlined in black. Metalled and main roads may be coloured brown.

Railway.—A broad red line.

Woods.—A green wash and no symbols.

Cultivation.—A yellow wash.

Villages and houses.—Black.

Troops.—British in red, Opposing forces in blue.

Entrenchments.—Red line.

In using paints one method is to first damp the surface to be painted ; having mixed sufficient wash, put it on and let it dry. This will ensure an even tint. Washes should not be too thick. With chalks, the pencil should be continually twisted round in the hand to keep an even breadth of line.

Water and Roads.—Apply a light shade all over and then rub in with a chamois leather or handkerchief.

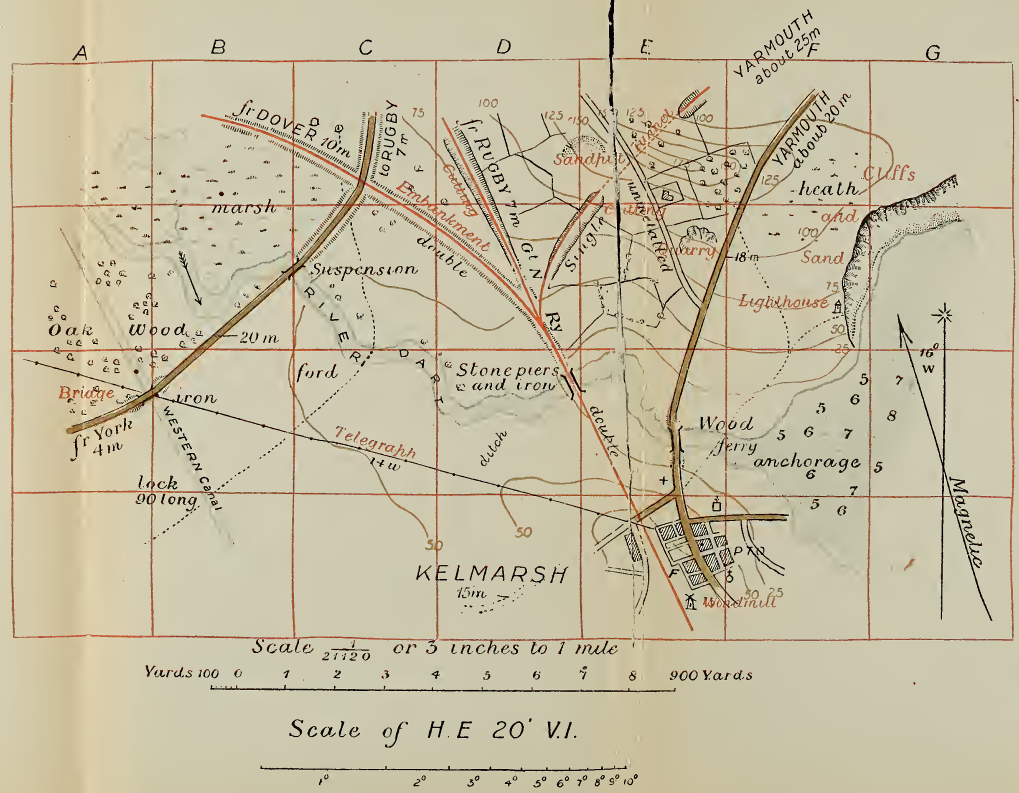
Woods and Cultivation.—A diagonal hachuring.

QUESTIONS.

1.—Draw a winding river, average width 200 yards, scale $\frac{1}{10560}$, and show, crossing it at various points : a double line of railway over an iron girder bridge on stone piers : a bridge of boats ; a masonry bridge : a flying bridge : and a ferry.

Plate XVI.

Anchorage	F 3.
Bank	D, E. 1, 2
Bridge	B 2, D. E 3
Canal	A, B, 2, 3.
Cliff	G, F. 1, 2,
Church with Tower	E 4,
" " Spire	F 4,
Church without	E 3.
Cutting	D, E, 1, 2,
Ditch	D 3,
Embankment	B, C. D, 1, 2,
Ferry	E 3.
Fence	D, E, 1, 2,
Forge	E 4,
Ford	C 3,
Garden	E 1,
Gravel Pit	D, E, 1.
Heath	F, 1, 2.
Houses	
Lake	A, B, 1,
Lighthouse	F 2,
Lock, Canal	B 3,
Marsh	A, B, C, 1, 2.
Metalling of roads	B 2, D 4, E 2,
North Points	G 2, 3, 4,



Orchard	E. F, 1,
Pond	A, B, 1.
Postal Telegraph Office	F 4,
Printing—see sketch	
Quarry	E 2,
Railway	B, D, E, 1-4.
Road, metalled A. C. 1-3. E. F 1 4.	
" unmetalled	E 1 2,
River	A, F, 2, 3,
Sand	F, G, 2,
Sandpit	D, E, 1,
Smithy	E 4,
Telegraph	A-E, 3, 4,
Telegraph Office	F 4,
Trees	A. B. 2. 3. C. D. 2, 3.
Tunnel	E 1,
Village	E 4,
Wall same as Fence, Bank	
Windmill	E 4,
Wood	A, B, 1, 2.

2.—Draw neatly the conventional signs for Vedettes: a Battery Horse Artillery on the march: a Sentry: Transport on the march: Infantry in line: the site of a battle: and for true and Magnetic North, showing a variation of 18½° West.

3.—Draw an imaginary piece of ground, about 6 inches by 4 inches, and introduce appropriately the following conventional signs:—

A river flowing from N.E. to S.W.: a seacoast, with sand, anchorage, and cliffs: a pier and lighthouse: roads, metalled and unmetalled, and with and without boundaries, and passing over embankments, and through cuttings: a pond: a marsh, and a line of telegraph.

CHAPTER V.

INSTRUMENTS AND THEIR USES EXPLAINED.

The Instruments generally available for Military Sketching are:—

A. The Pocket Sextant.
B. The Prismatic Compass, and Protractor.
C. The Plane Table.
D. The Clinometer and Abney Level for measuring slopes.
E. The Aneroid Barometer for reading heights.
F. The Chain, for lineal measurements.

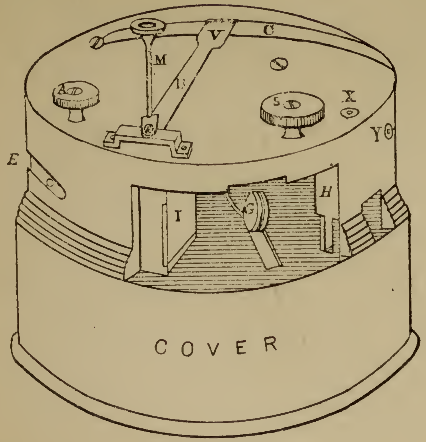
And, of course, every one must know how to keep a Field-Book.

The above instruments, &c., will now be fully described, their various uses explained, and their merits and defects for particular purposes compared. But it may be noted here, as has already been remarked in the Preface, that the use of the Pocket Sextant and Chain, for Military Sketching, is exceptional ; and a knowledge of the manner of working with them, though very desirable, is not absolutely necessary for a Regimental Officer, nor for promotion examinations. Moreover, it takes much longer to learn the intelligent use of the Pocket Sextant: it is an expensive instrument compared with the compass: and it requires time and skill to develop the fine work that it is capable of. In short, it is more adapted for *survey* (not *sketching*) operations, conducted by adepts, than for general use. The beginner, therefore, will do wisely to leave the Pocket Sextant alone until he has thoroughly mastered the use of the Prismatic Compass, and Plane Table. These are instruments whose use is very quickly learnt, with which excellent work can be turned out, and with which every Officer should be familiar. The Prismatic Compass, being as portable as a watch, would probably be the more generally useful of the two on service, but there is no doubt that in simplicity, speed, and accuracy, the Plane table is superior to it. Its want of portability is the only objection to the Plane table, though even this may be to a great extent, overcome, as will be explained presently. We may now proceed to consider each instrument separately, and learn how to use it.

I.—THE POCKET SEXTANT.

The Pocket Sextant is a reflecting instrument, and reads *angles* only, not *bearings.* The instrument ready for use is represented in *Plate* XVII., and the names of its different parts are there given.

The arc of the Sextant is generally graduated up to 120° or 130°, but it will be found that the actual angle contained between the graduations 0° to 120°, or 0° to 130°, is only 60°, or 65°, as the case may be. The reason for this is explained in the following remarks which illustrate the principle and construction of the instrument :—



SEXTANT

NAMES OF THE PARTS.

I.—*The index mirror.*

B.—*The index arm, with Vernier V, which moves with the index mirror.*

S.—*The screw by which the index mirror is moved.*

C.—*The graduated arc on which the observed angle is read off.*

M.—*The magnifying glass for examining the Vernier.*

H.—*The horizon glass—upper half only silvered.*

E.—*The eye-hole, into which (in some instruments) a telescope fits.*

G.—*Darkened glasses, used only for observations of the sun.*

A.—*The adjusting key.*

X & Y.—*Key-holes for adjusting the horizon glass.*

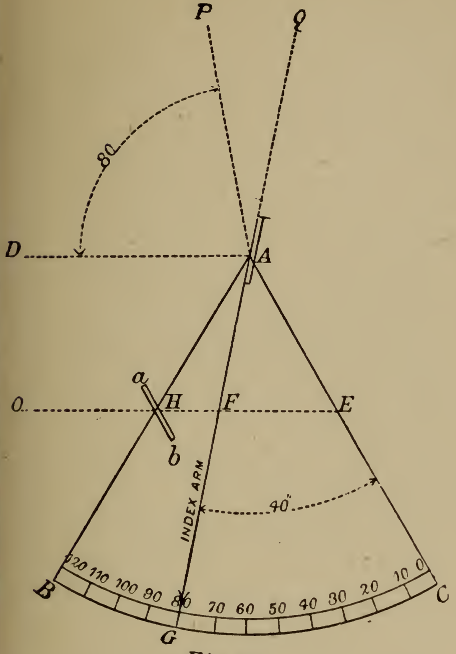


Fig. 13.

A B C (*Fig. 13*) is a Sextant. B C is the graduated Arc, H, or *a b*, is the horizon glass, fixed parallel to A C. A is the index mirror, and A G the index arm, which moves as the mirror turns and denotes the observed angle on the arc B C. E is the position of the observer's eye. Now if the index arm pointed to 0° on the arc, it is evident the glasses A & H would be parallel to each other. Let us suppose them in this position. Now let it be required to find the angle subtended at E by two distant objects, O and P. O is observed by direct vision through the lower half of the horizon glass H. And the index mirror is then turned until the right hand object P coincides with it by reflection in the upper half. The index arm will now indicate the angle on the arc B C. Now the true angle observed is (ignoring the effect of parallax) the angle P A D, the line A D being drawn parallel to E O, whereas the angle recorded, G A C, is (as will be proved immediately) only just half of the angle P A D; therefore to avoid a palpable error, all the graduations on the arc are doubled; or, in other words, an actual angle of 60° is divided to show 120°.

To prove that the angle P A D is double the angle G A C, or which is the same thing, double the angle F A E.

The angle of incidence P A Q is equal to the angle of reflection B A G, and the angle of incidence A H *a* is equal to the angle of reflection *b* H E. Also, the angle H E A is equal to the angle H A E, because A E and *a b* being parallel, the angles A E H, and *a* H O are equal; and *a* H O is equal to *b* H E; and *b* H E is equal to *a* H A; and *a* H A is equal to H A E (being alternate angles); therefore H E A is equal to H A E. Now the angles O F Q and D A Q are equal, but O F Q is equal to the two angles F A E, F E A; and F E A is equal H A E, therefore the angle O F Q, or D A Q, is equal to the angles F A E and H A E. Take away the equal angles P A Q and B A G, (or H A F) and the remaining angle P A D is equal to 2 F A E. Q.E.D.

The parallax of the Sextant.—To ascertain with absolute theoretical exactness the angle subtended by any two objects at the point of observation, the eye of the observer should be at the centre of the index mirror *(A Fig. 13)*. But as this cannot be conveniently arranged, the observation is made from E, a little to one side of it. This occasions what is called the parallax of the instrument. To define it: *it is the angle subtended at the right-hand object by the point of vision and the centre of the index mirror.* This angle is so small as to be barely perceptible when observing objects so close even as 400 or 500 yards. At half a mile all error vanishes. The effect of parallax—when the effect is appreciable—is to make angles up to about 25° read less than they ought to be: beyond this the angles observed would be greater than they really are: whilst at about 30° parallax produces no effect.

The adjustments of the Sextant.—Before using a Sextant make sure that it is in adjustment. To ascertain this, look at some sharply-defined object such as a telegraph-post, or the side of a house, &c., at least half a mile distant (to avoid the effect of parallax) and turn the index-mirror until the object and its own reflected image exactly coincide. The arrow on the Vernier of the index arm ought now to point to zero on the graduated arc. If it does not do so the instrument is out of adjustment. If the difference is something very small, say 5 minutes, it is better to note it, and add or substract 5′ from each observation made, than to meddle with the adjustments, which, if carelessly attempted, may injure the instrument. Thus, suppose the arrow pointed 5′ to the *right* of the zero on the arc—in other words, suppose the reading was 5′ when it ought to be 0′—then 5′ must be ***subtracted*** from every angle observed. And the 5′ would express what is called the index-error of the Sextant. It will be observed that there are divisions on the graduated arc to the *left* of the zero. These form what is called *the arc of excess.* If the arrow pointed to 5′ on this arc of excess, when the reading ought to be 0, then 5′ would have to be *added* to every angle observed.

To adjust the Sextant.—Two adjustments are necessary :—

The 1st.—To see that the two mirrors are parallel to each other when the arrow on the Vernier points to zero on the arc.

The 2nd.—To see that the horizon glass is perpendicular to the plane of the instrument.

For the 1st adjustment : Set the Vernier at zero, then look as before at some well-defined object at least half-a-mile off. Take out the adjusting key, *A*, *Plate* XVII., put it into the *side* key-hole Y, and by steadily turning it make the object, and its reflected image exactly coincide.

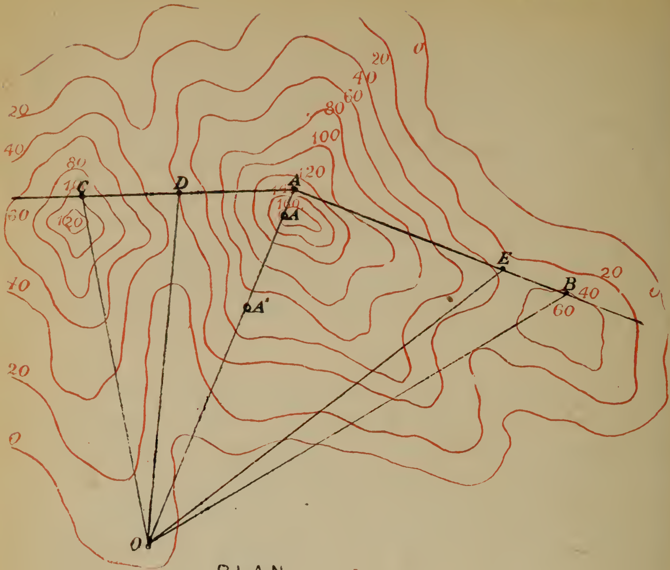
For the 2nd Adjustment : Look at the far horizon, if it and its reflected image appear as *two* horizons, put the key into the *top* key-hole, X, and turn till they appear as one only.

To observe an angle with the Sextant.—Hold the Sextant in the left hand, look at the left hand object, and turn the index mirror until the right hand object exactly coincides with it by reflection. Then read off the angle indicated on the arc. If from peculiarity of background, or light, it is preferable to look directly at the right hand object, and to make the left hand one coincide with it by reflection, then hold the Sextant upside down while making the observation.

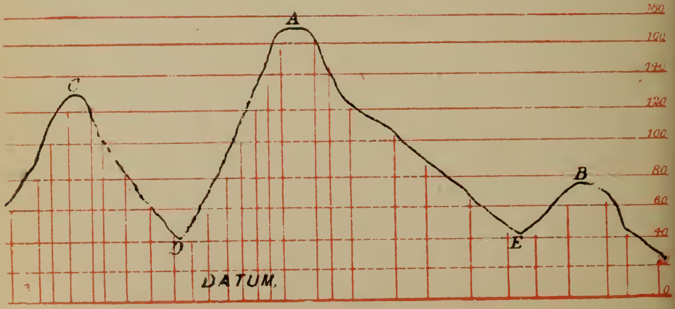
To measure a Vertical Angle.—Hold the Sextant in the right-hand, with its screws to the left. Look directly at the lower of the two objects, and bring the upper one down to coincide with it. Then read the angle off the arc as before.

The Pocket Sextant will not measure an angle larger than about 120°. This is one reason why it is not a suitable instrument for traversing (*See Definitions*). Sometimes, however, a larger angle must be measured. In such a case, an intermediate point must be noted, and the angles between it, and the left and right hand objects measured separately and added together. Thus, an observer at O wishing to measure the angle A O B, would have to select some intermediate conveniently situated point, such as C, and then first observe the angle A O C, and afterwards the angle C O B. Their sum would of course be the required angle A O B. (*Fig.* 14).

Very often it is required to measure the true horizontal angle between two objects which are not on the same level. In such cases care must be exercised, or mistakes will be made. The actual angle between the two objects can be readily observed by holding the sextant on a slant, so that its plane may be parallel to the two objects. But the angle thus obtained will be greater than the true horizontal angle, and if this angle was plotted, the direction of one of the objects at all events would be seriously out. To guard against this liability to error where an angle has to be measured between objects on different levels, the observer must, with the aid of a plumb line, endeavour to find some point vertically above or below one of the objects, and on the same level as the other object; and then measure the



PLAN.



SECTION ON THE LINE C.A.B.

angle between this point and the other object. It will be a much nearer approximation to the truth than if the angle had been measured in an oblique plane between the two objects.

Fig 14

Another expedient by which a close approximation to the true horizontal angle between objects on different levels may be obtained—suitable when the angular distance between them is small—is to select a third point about 90° or 100° away from them, and measure separately the angle between each of the objects and this point. The difference between the two observations will be the angle required.

The foregoing remarks will perhaps be better appreciated after a study of the following illustration.—*(See Plate* XVIII.*)*

An observer standing at O, facing a range of heights C A B, wishes with a sextant to fix the correct direction of the points, C A B and of the depressions between them, D and E. The section on the line C A B shows the difference in level between all these points, and it is evident that if he measures separately the angles subtended by C D, (*See Section*) D A, A E, and E B, their sum will come to a great deal more than the true horizontal angle subtended at O by the points C B; and if the angles thus observed are plotted, the result would be worthless, for the directions given to the various points would be wholly incorrect. Therefore, what he would do, would be by means of a plumb line to find a point A′, vertically below A (regarded from his position at O) and on the same level as C, and then measure the angle C O A′; this will give him the true relative directions of C and A, and he can plot them with confidence. The direction of B would be obtained in the same manner by measuring the angle A″ O B, A″ being a point found by the plumb line, vertically below A, and on the same level as B. Similar precautions would be used in making observations to get D and E.

Intersection with the Sextant. (*Plate* XIX.)—The Sextant is an instrument which in accuracy approaches the Theodolite, as it gives readings to within one minute. Some sextants indeed read to half minutes. Moreover, it is not like a compass affected by the neighbourhood of iron, or by bad weather. It is therefore specially adapted for accurate work like intersection. The process is quite simple. The angles observed must be methodically recorded, acute intersections must be avoided, and care must be taken (as previously explained) that all the angles are truly horizontal ones. A base A B is first selected and measured. Then standing at A, a round of angles is observed, and recorded thus:—

At A
From C to B – 64° 37′
,, D to B – 35° 49′
,, B to E – 48° 0′
,, B to F – 88° 21′
,, F to G – 51° 41′

Then proceeding to B another round is made and noted thus:—

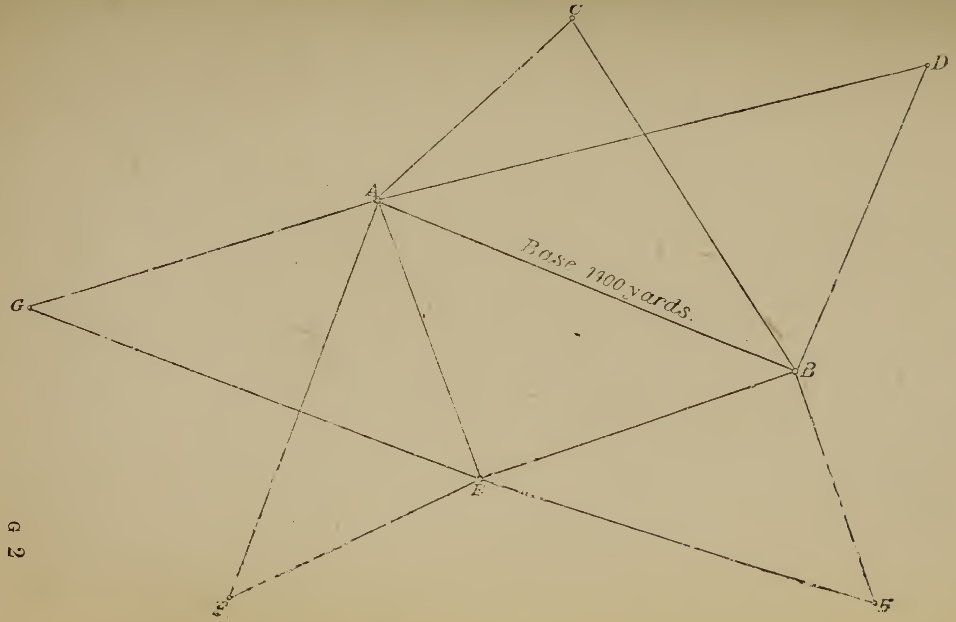
At B
From A to C – 35° 2′ (this fixes C.)
,, A to D – 90° 23′ (this fixes D.)
,, E to A – 41° 0′ (this fixes E.)
,, H to E – 89° 27′

We can now go to E, which has been fixed by the preceding observations, and note another set of angles, thus:—

At E
From F to A—95° 32′ (this fixes F.)
,, G to A—48° 10′ (this fixes G.)
,, B to H—36° 47′ (this fixes H.)

In this way, the triangles can be extended as may be required. The next thing is to plot, or transfer to paper,

INTERSECTION WITH THE SEXTANT.



the observations recorded. The instrument ordinarily available for Military Sketching purposes is the ivory protractor. But this protractor is only graduated to *degrees*, and therefore it is wholly unsuited to protracting angles measured with a sextant, for it would be obviously of little avail to observe an angle to within *one minute*, unless it can be laid down on paper with something like corresponding accuracy. Consequently, to plot an intersection of stations observed with a Sextant, one of the three methods described below must be had recourse to :—

(a) The observed angles may be protracted by means of a *Circular or Semi-Circular* protractor. These protractors are made of various sizes, and generally provided with Verniers, giving readings sometimes to one minute. They are, however, delicate and expensive instruments, troublesome to use, and not adapted to field work. Another kind which is sufficiently accurate, and much simpler to use, is made of cardboard, in sizes varying from 12ins. to 18ins. in diameter, and graduated down to 15 minutes, so that angles may be laid down by estimation to within 5 minutes. The use of these is recommended. In practice it will be found a good plan to cut a small hole out of the centre of one with a stirrup-punch, so that it can be accurately adjusted to the point at which the angles are to be laid off. To mark off the angles, a needle, or a very finely-pointed pencil must be used, and the protractor must be kept perfectly steady throughout the operation.

(b) On most ivory protractors is engraved *a scale of Chords*, marked C, or C H O. By its means, angles can be protracted much more accurately than by simply laying them off with the protractors in the ordinary way. Therefore, if a circular cardboard protractor is not available, the Scale of Chords may be used with advantage for plotting the triangulation. Subjoined is an example of its use.

At the point A in the line A B, it is required to lay off the angle C A B = 64° 37′, D A B = 35° 49′.

From the Scale of Chords take in the compasses the distance from 0 to 60°, and with A as centre, and radius equal to this distance, describe the arc E F, cutting A B (prolonged if necessary) in F. Then with centre F, and radius F C = 64° 37′ (taken off the scale of chords) and F D = 35° 49′, describe arcs cutting F E in C and D. Join the points of intersection with A, and the angles thus formed, C A B, and D A B, will be the angles required. (*See Fig.* 15.)

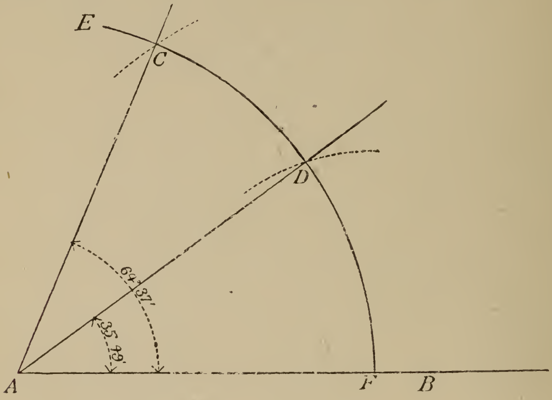


Fig. 15.

(c) The third, and most accurate, method of laying down the triangulation is *by calculation.* In the triangle A B C, (*Fig.* 16) if the side A B is known to be 6,000 feet,

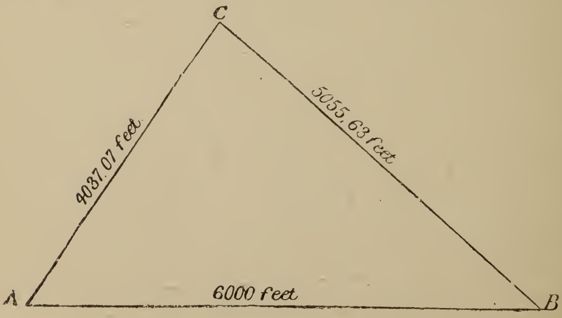


Fig 16.

and the sides A C and B C can be calculated to be respectively 4037.07 feet, and 5055.63 feet, then it is evident that the position of C can be very accurately fixed by describing arcs with centres A and B, and radii 4037.07 feet and 5055.63 feet respectively. The intersection of the arcs so described will, of course, exactly fix C. Now the sides of any triangle can be calculated if we know certain things about it. We must know either two of its angles (in which case we, of course, know the third angle also) and one of its sides: or, we must know two of its sides, and the included angle. One of the above conditions being complied with, the calculation of the sides is a mere matter of a little time and trouble: but whenever the time is available the trouble should be taken, for this method is by far the most accurate of all, and therefore it is recommended always to *calculate the sides of the principal triangles* whenever it is practicable to do so. In this way only can the full benefit of working with such an accurate instrument as the Sextant be reaped A couple of examples are given below.

1.—A base A B is measured to be 6,000 feet exactly. The angle B A C is observed to be 56° 30′, and the angle A B C 41° 45′. The angle at C, therefore, must be 81° 45′. Required the length of the sides A C and B C.

The rule for solving a triangle when its angles and one of its sides are known is this: *The sides of a triangle are to each other as the sines of the opposite angles.* Therefore, in the triangle A B C.

$$AB : AC :: \text{Sin. } C : \text{Sin. } B$$

or, it may be more conveniently stated, thus :—

$$\text{Sin. } C : \text{Sin. } B :: AB : AC$$

$$\text{or, Sin. } 81^\circ\ 45' : \text{Sin. } 41^\circ\ 45' :: 6{,}000\text{ft.} : A\,C$$

$$\therefore A\,C = \frac{\text{Sin. } 41^\circ\ 45' \times 6{,}000}{\text{Sin. } 81^\circ\ 45'}$$

$$\left.\begin{array}{l}\text{The natural Sin. } 41^\circ\ 45' = .6658817\\ \text{The natural Sin. } 81^\circ\ 45' = .9896514\end{array}\right\}\text{Taken from the Table of natural sines.}$$

$$\therefore A\,C = \frac{.6658817 \times 6000}{.9896514} = 4037.07 \text{ feet.}$$

And B C, calculated in the same way will be found to be 5055.63 feet.

It is usual however to use logarithms in making these calculations; and to simplify the process, *the cosecant of the angle opposite the known side is used instead of the sine.** The proportion would then stand thus :—

$$\frac{1}{\text{Cosec. C.}} : \text{Sin. B} : : \text{A B} : \text{A C}$$

$$\therefore \text{A C} = \text{Sin. B} \times \text{A B} \times \text{Cosec. C}$$

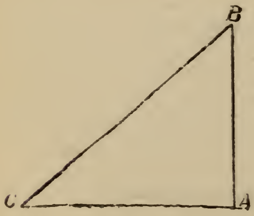
By logarithms :—

$$\begin{aligned}\text{Log A C} &= \text{log. sin. B} + \text{log A B} + \text{log. cosec. C.}\\ &= \text{log. sin. } 41^{\circ}45 + \text{log } 6000 + \text{log. cosec } 81^{\circ}\ 45\\ &= 9.8233971 + 3.7781513 + 10.0045178\\ &= 3\ 6060662\end{aligned}$$

and therefore, A C = 4037.07 feet.

In the same way, B C will be found to be 5055.63 feet, if calculated from the proportion $\frac{1}{\text{Cosec. C}}$:Sin. A : : AB:BC.

2.—In the triangle A B C, *Fig.* 17, the side A B is known to be 2000 feet, and the side B C, 3000 feet, and the angle between them 80°. It is required to calculate the angles at A and C, and the length of the side A C.



In the triangle A B C, Sin. C=$\frac{\text{B A}}{\text{B C}}$

and Cosec. C=$\frac{\text{B C}}{\text{B A}}$

$\therefore$ Sin. C= $\frac{1}{\frac{\text{B C}}{\text{B A}}} = \frac{1}{\text{Cosec. C}}$,

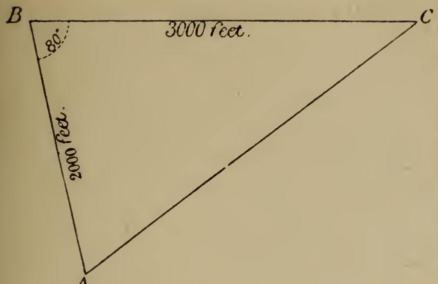


Fig 17.

In this case the rule is :—
As the sum of the two known sides is to their difference, so is the tangent of half the sum of the two unknown angles to the tangent of half their difference. Half their difference thus found added to half their sum, will be the larger of the two angles required, viz., that opposite the largest side. All the other parts of the triangle can then be found as before.

Therefore, by the rule just stated, *we* have—

$$5000\text{ft.} : 1000 \text{ feet} :: \text{Tan. } 50^\circ \quad \text{Tan. } \frac{A-C}{2}$$

$$\therefore \text{Tan. } \frac{A-C}{2} = \frac{1000 \times \text{tan. } 50}{5000}$$

$$\therefore \text{Log. tan. } \frac{A-C}{2} = \text{log. } 1000 + \text{log. tan. } 50^\circ - \text{log. } 5000$$

$$= 3.0000000 + 10.0761865 - 3.6989700$$

$$= 9.3772165$$

And therefore, $\frac{A-C}{2} = 13^\circ\ 24'\ 22.8''$

$\therefore$ The Angle B A C $= 50^\circ + 13^\circ\ 24'\ 22'' = 63^\circ\ 24'\ 22''$
and B C A $= 50^\circ - 13^\circ\ 24'\ 22'' = 36^\circ\ 35'\ 38''$

Now all the angles being known, A C can be readily calculated as before, thus:—

$$\frac{1}{\text{Cosec. A}} : \text{Sin. B} :: \text{B C} : \text{A C}$$

or, $$\frac{1}{\text{Cosec. } 63^\circ\ 24'\ 22''} : \text{Sin. } 80^\circ :: 3000\text{ft.} : \text{A C}$$

$\therefore$ A C = Sin. 80° × 3000 × Cosec. 63° 24′ 22″
$\therefore$ log. A C = log. sin. 80° + log. 3000 + log. cosec. 63° 24′ 22″
= 9.9933515 + 3.4771213 + 10.0485645
= 3.5190373
And therefore A C = 3303.97ft. *Answer.*

N.B.—When triangles are laid down by their sides, it is usually done with Beam Compasses, to ensure the greatest accuracy, but a pair of common compasses may be used if they are carefully manipulated. It may be noted here that the bearing of the base-line of a triangulation should be always taken with a Prismatic Compass. Its bearing being known, the true and magnetic meridians can then be correctly shown on the sketch by the proper conventional signs. (*See Page* 44).

Resection with the Sextant.—To resect your position, means to determine the exact spot on your sketch at which you are standing, by means of observations made on distant objects, which are already laid down on the sketch. To do this with a Sextant, *three* such objects must be visible. With a Prismatic Compass, or Plane Table with a compass, only *two* are necessary, but three points are desirable. (*See* Interpolation, *Page* 108).

The various methods in which resection may be effected with a Sextant are described below :—

1st Method.—An observer standing at O, wants to find his position on his sketch, on which the three points A B C visible from where he is standing, are already laid down. (*Fig.* 18.) He first, with the Sextant, observes the angle A O B to be 35°, and the angle B O C to be 47°. He then takes his sketch, and joins A B, B C, and from B draws the line B D in any convenient direction. Next, from A, he draws the line A E, making an angle of 35° with B D : and from C, the line C F, making an angle 47° with B D. Then about each of the triangles A E B, and B F C, he describes a circle, and finds that his true position is at the point O, where the circumferences of the circles cut each other. For if from the point O lines are drawn to A, B, and C, and the angles A O B, B O C measured, it will be found that they are 35° and 47° respectively, and, therefore he must have been standing at O when he observed these angles.

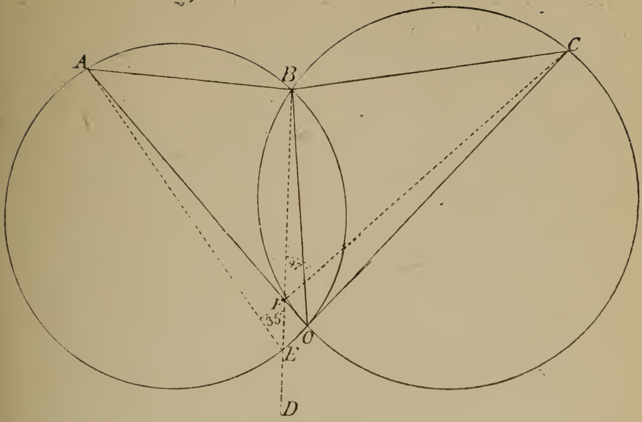


Fig. 18.

This solution is based on the fact that in triangles inscribed in the same circle, and on the same base, the angles at the circumference are equal.

2nd method, conditions the same as before. (*Fig.* 19).

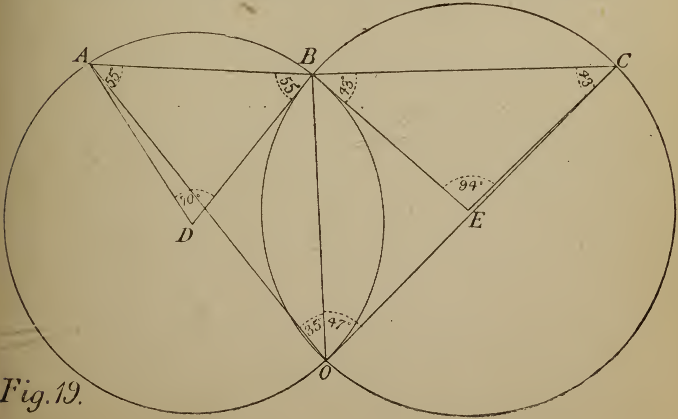


Fig. 19.

This solution is based on the fact that in triangles on the same base, and inscribed in the same circle, the angle at the centre is double the angle at the circumference.

The angles observed are, as before, A O B, 35°, and B O C, 47°. Now 35° being the angle at the circumference, the angle at the centre must be 70°; and this centre will be found by drawing the lines A D and B D, each making an angle of 55° with A B, until they meet in D. For in the triangle A B D, the angles D A B, and A B D must together be equal to 180°−70° = 110°; therefore each of them must be 55°. Then, with centre D, and radius D A, or D B, describe a circle. The observer's position must be somewhere in its circumference. In the same way, the centre E is found, and with radius E B, or E C, another circle described, when it becomes obvious that the observer's position must be at the point O where the circumferences intersect.

This method is rather a clumsy one, and involves setting off so many angles that the result is not to be relied on for extreme accuracy.

It may happen that one, or both, of the observed angles is over 90°. The calculation must then be made for *the supplement* of the observed angle, and the centre of the circle will be found on the far side of the line joining the two points which subtended the angle concerned.

For Example.—A B C being the visible points, the following angles are observed: **A O B 47°**, and B O C 120°. Find O. (*Fig.* 20).

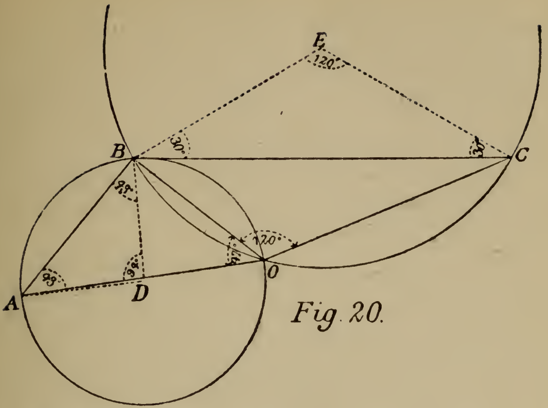


Fig. 20.

D is found as before explained, and the circle A B O described.

To find E, we must work with the supplement of the observed angle 120°, that is, 180°−120 = 60°. The rest of the process is the same. Double 60°, and we get 120° for the angle at the centre E, and therefore the angles E B C, E C B, must each be 30°, and by setting them off E is found. Then, with E as centre, and radius E B or E C, the circle B O C is described, and the observer's position fixed at the point O, where the two circumferences intersect.

3rd method.—This method is a very simple and practical one. It is called *finding the position by adjustment.*

Take a piece of tracing paper, and from any point on it O, draw three lines O A, O B, O C, making the angles A O B, and B O C, equal respectively to the observed angles. Then lay the tracing paper on the sketch, and shift it about till the lines O A, O B, and O C, pass exactly through A, B, and C. Then prick through O, and your position is found.

FURTHER USES OF THE SEXTANT.

The Sextant is very useful for laying out angles quickly on the ground, and for measuring heights and distances

These may be ascertained by construction, by calculation, or by the help of the scale of tangents which is engraved on the cover of most instruments.

EXAMPLES.

1.—*To lay out a right angle on the ground.*—A line is required in the direction C,(*Fig.* 21) making a right angle at the point B with the line A B.

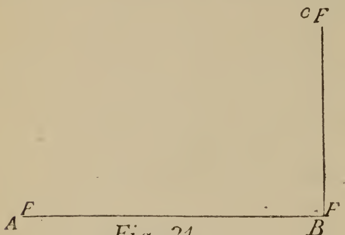


Fig. 21.

Set the sextant at 90°. Stand at B, and look through the sextant at a flag planted at A, having first sent a man out towards C with another flag. Make this man move to the right or left until the flag he holds coincides exactly by reflection with the flag at A. Then let him plant his flag in the ground. A line drawn from it to B will be at right angles to B A.

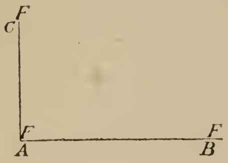


Fig 22.

If the right angle had been required at A, the sextant would have been held upside down, and directed on B, and the man moved about as before until his flag coincided with the flag at B. (*Fig.* 22.)

In the same way *any angle* can be laid out with the sextant; only remember always to look directly at the left-hand object: if it is necessary to look directly at the right-hand object, as it may be sometimes, then the sextant must be held upside down.

2.—*To measure a distance.*—(*a*) By construction. Let it be required to measure the distance A x. (*Fig.* 23). Select and measure any convenient base A B. From its ends observe the angles xA B, xB A. Plot the base on some *large* scale, and set off the angles observed. This will fix the position of x, and the distance A x can then be measured off the same scale by which the base was plotted.

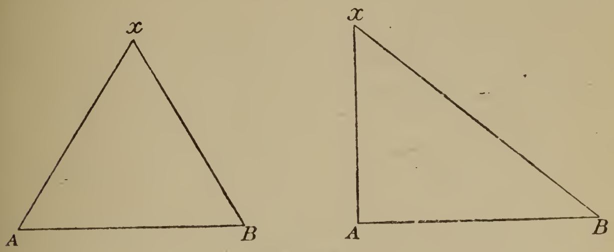


Fig. 23.

(b) By calculation.—The side A B being known, and the angles at A and B, the side A x can be calculated, as previously explained.

(c) By the Scale of Tangents.—This method is particularly applicable to measuring short distances, such as the breadth of a river, the height of a wall, &c. Subjoined is the scale referred to:—

Multiplier.	Angle.	Angle.	Divisor.
1	45°	45°	1
2	63° 26′	26° 34′	2
3	71° 34′	18° 26′	3
4	75° 58′	14° 2′	4
5	78° 41′	11° 19′	5
6	80° 32′	9° 28′	6
8	82° 52′	7° 8′	8
10	84° 17′	5° 43′	10

3.—Let it be required to measure the distance A x.

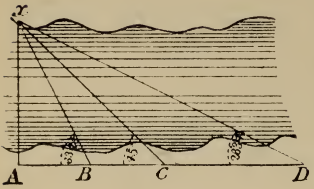


Fig. 24.

First lay off the right angle x A B. Then set the sextant at any one of the angles given in the table, and walk backwards in the direction of B, until a point is reached, at which x is seen by reflection to coincide exactly with A. Then measure the distance from A to this point, and according to the angle you have used, multiply or divide it by the correct multiplier, or divisor. The result will be the correct distance A x.

Suppose, for instance, the sextant has been set at 63° 26′, and the point B found. The multiplier for this angle is 2°; therefore the distance A x would equal twice the distance A B. If it had been set at 45°, and the point C found, the distance A x, would be the same as the distance A C, because the multiplier or divisor for 45° is 1. If the angle 26° 34′ had been used, and the point D found, the distance A x would be only half the distance A D, as 26° 34′ is one of the divisor angles, and the divisor to be used with is 2. And so on.

4.—The following useful example is extracted from *Drayson.*

It is required to measure the distance A x, but a base cannot be measured except at B C. (*See Fig.* 25).

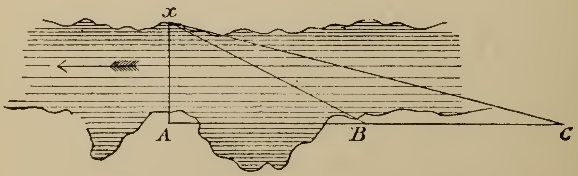


Fig 25.

From A lay off a right angle as usual. Set the sextant at any of the divisor angles, the nearer 45° the better, say at 26° 34′. Then by trial find the point B at which this angle is subtended by A x. Then move back along the line B C until you find another point C, at which a smaller angle, say 14° 2′, is subtended by A x. Now the divisor given in the table for 23° 34′ is 2; and that for 14° 2′ is 4, and the difference between these numbers is 2; therefore, if the distance B C be measured, and divided by 2, the result will be the correct distance A x.

5.—To measure the height of an accessible object A B (*Fig.* 26).

Make a mark C on the object, the height of your eye above the ground, say 5 feet. Then set the sextant at one of the angles in the table, say 26° 34′, and step back to D; that is, until the point B coincides by reflection with the mark C; measure the distance A D; divide it by 2, the divisor given for 26° 34′; and the quotient, plus 5 feet, will be the height of A B.

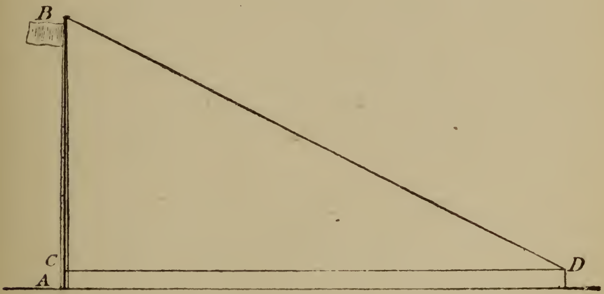


Fig. 26.

6.—To measure the height of an inaccessible object A B. (*Fig.* 27).

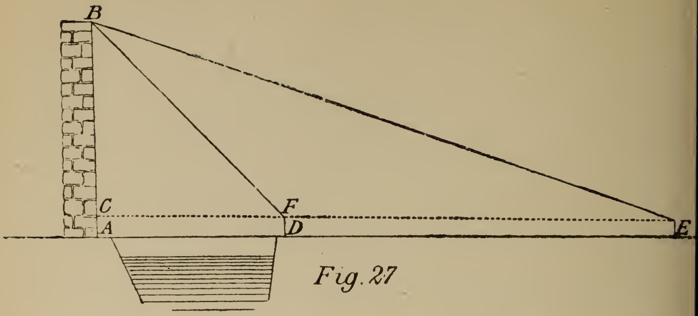


Fig. 27

Get as close to A B as possible, so as to use the largest angle you can. Suppose you can work with 45°. Setting the sextant at that, you find a point D at which B coincides exactly with C, a spot the height of your eye above the ground. At D, plant a stick F, equal in height to C; then set the sextant at one of the lesser angles in the table, say 18° 26′, and step back till a point E is found at which B and F coincide. Then measure the distance D E, and divide it by 2, *the difference between the numbers in the table opposite the angles used*, and the quotient, plus A C, or D F, will be the height of A B.

Now that the height of A B is known, the distance A E can be ascertained by multiplying it (minus the bit A C) by 3, which is the multiplier given for the angle 18° 26′ which was used at E, and D E being subtracted from it, the distance A D is obtained.

It should be noted the parallax of the sextant exerts an influence on measurements of this kind, the objects being so close. To correct it, set the instrument at zero, and look at the top of the object. It, and its reflected image, will not exactly coincide. Make them coincide by slightly moving the index-arm. Then note the quantity indicated on the arc of excess (it will only be a few minutes), and subtract it when setting the sextant at any of the tabular angles. Thus, in the preceding example, if the error had been 10′, the sextant should have been set at 18° 16′, instead of at 18° 26′.

The chief uses of the sextant, and the manner of using it, have now been explained. After attentively reading the instructions and examples given in the foregoing pages, anyone ought to be able to work it with facility after a few days practice in the field. It only remains to sum up its advantages and defects, and compare them with those of the Prismatic compass about to be described.

Its advantages are that—

(a) It is very handy and portable, and strong and easily adjusted.

(b) It is very accurate, giving readings to 1 minute, and sometimes less.

(c) It can be used in rough weather, or even on horseback.

(d) It is useful for quickly laying out angles on the ground.

(e) It is useful for measuring heights and distances.

(*f*) It is not affected (as a compass is) by the neighbourhood of iron.

Its defects are that—

(*a*) The angles observed with it are not always horizontal angles.

(*b*) It is not nearly so well adapted as a compass for traversing, or for filling in the details of a sketch, because—

1.—It will not read an angle larger than about 120°.

2.—Any observation made with it, or any line plotted, must depend upon one that has preceded it: consequently any error that is made would go on increasing all through a traverse. (*See page* 105.)

3.—Resection with a sextant requires three fixed points. With a compass only two are necessary.

(*c*) Not being a magnetic instrument, it does not help you to find your way, or keep your direction in a strange country.

In short, for accurate work, like the observation of a regular triangulation, or for particular work, such as measuring heights and distances, or laying out field-works, &c., a sextant is *the* instrument to use; but in traversing, sketching in details, &c., the Prismatic Compass is far preferable.

II.—THE PRISMATIC COMPASS.

One form of the Prismatic Compass consists of a shallow circular metal box, about ½ an inch deep, and 2½ or 3 inches in diameter. In its centre is a short upright pin, or agate point, on which is balanced a magnetic needle, to which is attached a circular card so that the card moves with the needle. The rim of th card is divided into degrees and half-degrees, from 0° to 360°—sometimes into degrees and *thirds* of degrees. To one side of the rim of the box is fixed a folding sight-vane with a horse-hair down its centre, and directly opposite to it is a glass prism enclosed in a metal case, with a slit in it through which the horse-hair can be seen. The vane and the prism are so fixed that a line from the middle of the slit to the horse-hair would pass exactly over the centre of the card. There is a small knob under the vane, outside the rim of the box, by pressing on which the card can be stopped from swinging about When the instrument is not in use, the sight-vane folds down flat on the top of the box, and throws the needle off the agate point. The compass can then be carried about in the pocket without being liable to injury.

The Service Prismatic Compass (*Fig.* 27*a*) differs in that it has a metal lid opening on a hinge with a glazed window and hair line on it, which does duty for a sight vane. In case the glass smashes, small holes above and below the line are pierced in the metal, through which cotton can be threaded.

There is a brass ring attached for convenience in holding and for a strap.

For night work the card is luminous; there is also a broad strip of luminous paint in the lid and the North Point is marked with a large black diamond-shaped figure. For marching on a compass bearing, a revolving glass, with a black line on it, is fitted over the card. At the end of the black line is a small vane, to facilitate setting. The outside of the box is divided into 72 parts showing divisions of 5°, and each division of 10 being numbered 1, 2, 3, 4, etc., from N. to E. and S. and so round.

Fig. 27a.

The Service Luminous Prismatic Compass.

THE GRADUATION OF THE COMPASS CARD.—*The numbers on the card are reversed with regard to the direction of the needle.* That is to say, the north point is numbered 180° instead of 360°: the east is marked 270° instead of 90°: and so on. This is, of course, necessary to bring the observed bearing under the eye.

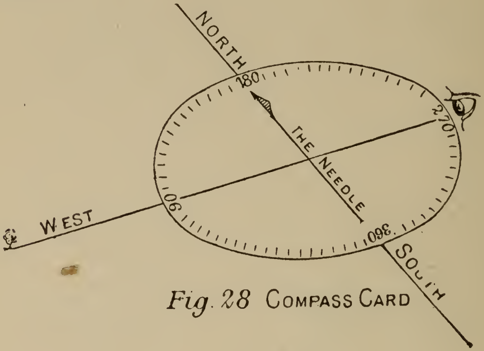


Fig. 28 COMPASS CARD

Fig. 28 shows this plainly. The bearing of the tree due west of the observer must be 270°; but this reading can only be obtained by commencing the numbering of the card at the south end of the needle; or, in other words, by reversing the graduation with regard to the direction of the needle.

Beginners are very apt to confuse *bearings* with *angles.* Let it be remembered that the Prismatic Compass gives bearings only, *not* angles, but the angle between two objects can be obtained by observing the bearings of two objects and noting the difference.

To use the Prismatic Compass, i.e., to take the bearing of an object, turn up the prism and sight-vane, taking care that the latter is perfectly upright. Stand facing the object whose bearing is required, hold the compass up in front of the body with both hands, and wait till the card has nearly done oscillating. If its swing is excessive, check it a little by pressing the knob under the sight-vane. Then raise it steadily to the eye, and look through the slit in the prism at the object, taking care to keep the compass quite level all the time, otherwise the rim of the card may touch the compass box, and be checked in its swing. When the horse-hair is accurately aligned on the object, and the card has come to rest, note the degree on the card cut by the hair. This will be the bearing of the object.

It requires practice, and a certain amount of knack, to take bearings quickly and accurately. It should also be remembered that different compasses will often give different readings, the difference between them being sometimes as much as 3° or 4°. If several bearings have to be taken from one spot, it is a good plan, *if the memory can be trusted*, to take two or more of them, before removing the instrument from the eye. By slowly turning round, and observing each point in succession, much oscillation of the needle, and consequently much valuable time will be saved. In rough, windy weather, it is very difficult, and sometimes impossible to take bearings reliably. By sitting down and resting the elbows on the knees, or leaning against a tree, &c., something may be done to facilitate an observation. Some compasses are made to screw on to a light folding stand. This is a very good arrangement, greatly facilitating quick and accurate work ; but the stand means extra weight on service, and the Military Sketcher should therefore accustom himself to work without one. Sometimes the object whose bearing is required cannot be seen from the observer's position, but can be seen if he advances a few paces, or moves a little to the right or left. It is one great advantage of working with a prismatic compass that he may do either of these things, and still get a correct bearing ; for suppose he is standing at A (*Fig.* 29) and can only see B, whose bearing is required, by advancing to *a*, or moving to A′, 20 yards to his right. It is evident in the first case that the bearing of B is the same whether taken from A, or from *a* ; and in the second, that if he takes the bearing of B′, a point 20 yards to the right of B, that he gets the same bearing as if B had been observed directly from A, for the lines A B and A′ B′ are parallel to each other.

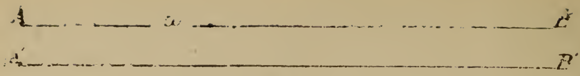


Fig 29.

This last expedient must be resorted to when the bearing of a line of railway has to be observed. The proximity of any iron affects the needle, and the bearings become unreliable. In some localities (notably in South Africa) the local attraction is so great, owing to the presence of large quantities of iron ore in the ground, that a Prismatic Compass cannot be used at all.

The Service Prismatic Compass (*Fig.* 27*a*), in addition to use as an ordinary Prismatic Compass, may also be used for :

Marching on Compass bearings by day and night.
Plane Table Compass.
Map Reading Compass.

To use it for marching on a bearing :—

Set the black index line to the required bearing, that is, see that the end of the black line is exactly over the bearing marked on the outside edge.

With the lid wide open and away from you, turn round until the N. point on compass card corresponds with the black index line. The centre line of the lid shows the direction in which to march.

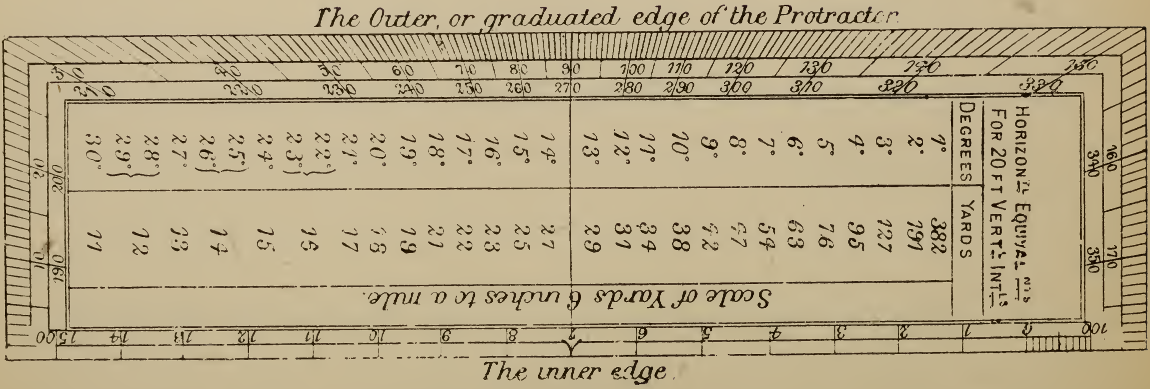
By tying a piece of thread to the brass ring and holding it up with one hand so that it cuts the line of direction shown in the lid, one can see on what distant point to march.

For night work the same rules apply, only instead of the centre line the luminous line in the lid gives the direction of advance.

Should the luminosity require reviving expose the compass opened out to the sun or broad daylight. Failing this burn some magnesium wire just before commencing work.

To use as a Plane Table or Map Reading Compass open the compass out and lay it flat on the sketch so that the notches on ring and at top of lid are on the magnetic N.

THE PROTRACTOR



HORIZONTL EQUIVALNTS
FOR 20 FT VERTL INTLS

DEGREES	YARDS
1°	382
2°	191
3°	127
4°	95
5°	76
6°	63
7°	54
8°	47
9°	42
10°	38
11°	34
12°	31
13°	29
14°	27
15°	25
16°	23
17°	22
18°	21
19°	19
20°	18
21°	17
22° 23°	16
24°	15
25° 26°	14
27°	13
28° 29°	12
30°	11

and S. line of your sketch ; then twist the sketch round till the north points on compass card and sketch coincide. The sketch or map is then set.

Plotting the bearings.—The Protractor.—(*Plate* XX.) Compass bearings are always plotted with the ordinary sketching *Protractor.* Of these there are innumerable kinds ;* some made of ivory, others of boxwood, and with various scales and memoranda, engraved on them. All are about the same size, viz., six inches long, by 1⅔ inches wide ; but all are not graduated in the same way. Some are only graduated up to 180°. These are no good for sketching purposes. The sketching protractor must show graduations up to 360°. Along one edge, called its *graduated* or *outer edge*, the degrees of the semi-circle from 0° to 180° are marked ; and just inside these, the graduations are continued from 180° to 360°. The opposite edge of the protractor, called its *inner edge*, has no degrees marked on it ; its centre is shown by a broad arrow ; and *this edge represents the direction of magnetic North and South.* Keeping this in mind, it is a simple matter to plot any bearing. The sketching paper must first be ruled with magnetic meridians. (*See Definitions*). Then the protractor is laid with its *inner edge* parallel to one of them, and the "broad arrow" touching the point at which the bearing is to be plotted. Then with a fine-pointed pencil the required degree is marked off, and the protractor being removed, a fine line is drawn from the point of observation through the mark made. This is the required bearing. There is only one thing to remember : if the bearing to be plotted is anything up to 180°, the graduated edge of the protractor must be turned *to the right of North*, and for any bearing between 180° and 360° it must be turned to the *left of North.* No mistake can possibly be made if the simple precaution be taken of making a small circle in the corner of the sketching paper, and marking on it the four cardinal points, and the degrees respresenting them. (*See Plate* XXI., *Figs.* 2 *and* 3). It can then be seen at a glance in what

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* Gale & Polden's Registered Sketching Protractor is an excellent one.

direction any particular bearing must fall, and it is impossible then to turn the protractor the wrong way. As a bearing is plotted, it is usual to write along it what it is, thus :—"*To Flagstaff*," "*To Palm-tree*," &c., otherwise one line may afterwards be mistaken for another, and confusion and loss of time will be the result. The writing should be very faint, so that it can be rubbed out when no longer wanted, without injuring the surface of the paper.

THE PROTRACTOR.

The service protractor (Plate XXA) is 6 inches long and 2 inches wide. On it four scales of yards are shown :—

$2\frac{1}{2}$ inches to a mile ; 2 inches to a mile ; 1 inch to a mile ; $\frac{1}{2}$ inch to a mile.

Three scales of miles are shown :—

$\frac{1}{80000}$ or 1 inch to 1·26 miles ; $\frac{1}{100000}$ or 1 inch to 1·58 miles ; $\frac{1}{250000}$ or 1 inch to 3·94 miles. Each of these has a corresponding scale of yards.

There is also a scale of kilometres $\frac{1}{100000}$.

The flat side of the protractor has a diagonal scale which gives measurements to two decimal places of an inch.

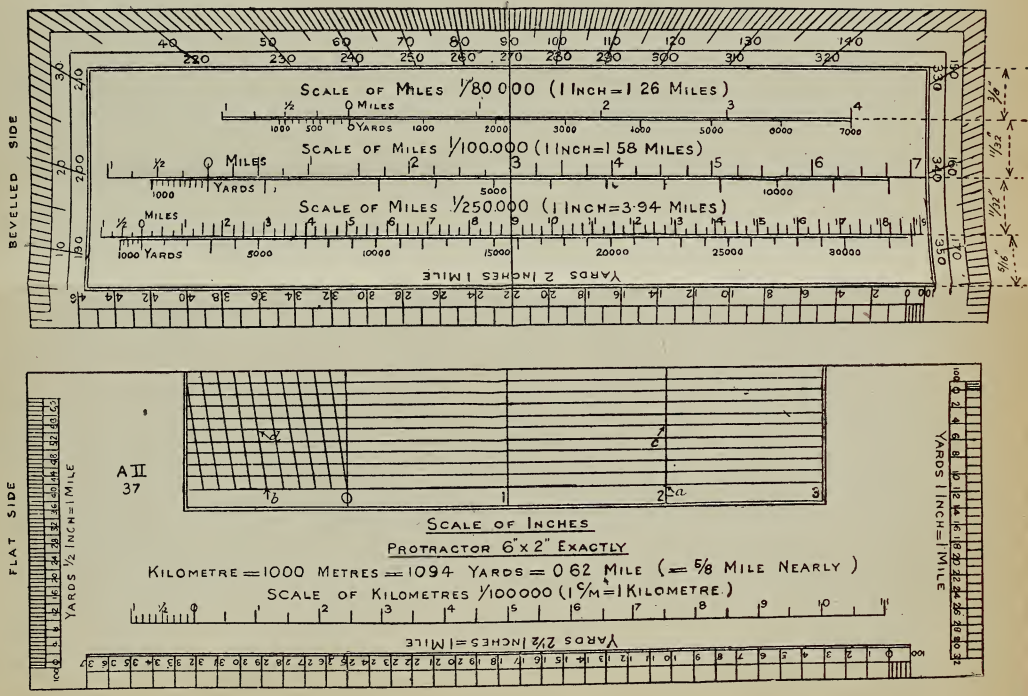
On the bevelled side, the outer edge is graduated to show the degrees of the semi-circle from 0° to 180° ; inside these the numbers are continued from 180° to 360°.

At the middle of the inner edge is the centre from which all angles are drawn ; this centre is generally indicated by an arrow head or star, though on the present service protractor there is only a straight line drawn across the middle.

Plate XXa.

PROTRACTOR RECTANGULAR.

6″ WOOD. "A" MARK II.



QUESTIONS FOR PRACTICE.

1.—Plot the following. Scale 6 inches to a mile. Variation, *nil.*

A to B	bearing	215°	distance	500	yards.
B to C	,,	172°	,,	340	,,
C to D	,,	113°	,,	460	,,
D to E	,,	158°	,,	370	,,
E to F	,,	182°	,,	480	,,
F to G	,,	250°	,,	320	,,

Find, and write down the length of a road from A to G *viâ* D, and determine its bearings.

2.—Construct a triange of which the side A B is 250 yards, B C, 350 yards, and A C, 520 yards—the point C bearing 90° from A, and the point B lying *above* the line A C. From A and C, bearings are taken to a point D as follows:—from A, 125° : from C, 200°.

Find D, and its distance and bearing from B.

Scale, 100 yards to an inch. Variation, *nil.*

3.—Plot the following to any convenient scale. One of the bearings is wrong. Correct it, giving reasons.

A to B	bearing	45°	distance	660 feet.
B to C	,,	315°	,,	1 furlong.
C to D	,,	225°	,,	10 chains.
D to A	,,	137°	,,	220 yards.

4.—If B bears 30° from A, and 330° from C, and the line A B = $\frac{1}{2}$ BC, what is the value of the angle B A C? *Answer*, with an explanatory diagram.

5.—Plot the following traverse on a scale of 6 inches to a mile.

A to B	bearing	5° 45′	distance	170 yards.
B to C	„	49° 15′	„	210 „
C to D	„	337° 0′	„	12 chains.
D to E	„	13° 45′	„	220 paces.
E to F	„	92° 30′	„	550 links.
F to G	„	300° 0′	„	400 yards.

Write down the distance from A to G, and the bearing of the line A G.

6.—From a point on the shore the bearing of a vessel at anchor is 330°. The observer, who has no means of drawing to scale, walks two miles westward along the beach, which bears due East and West, and again takes the bearing of the vessel, which is now 30°.

The vessel now weighs anchor and steams due West, the observer at the same time continuing his walk in the same direction as before. After walking a mile further, he observes the bearing of the vessel for the third time, and finds it to be again 330°. The magnetic variation being *nil,* what are the distances of the vessel from the observer at the first, second, and third observations? and what distance has the vessel traversed between the second and third? Supposing the observer to have been walking at the rate of 4 miles an hour, at what rate per hour has the vessel been going?

To draw magnetic meridians on the sketching paper.—It has just been stated that before a bearing can be plotted the paper must be ruled with magnetic meridians. Now the question is: How are they to be ruled? It is too often assumed that they must be straight up and down the paper; in other words, that the top of the paper must be the North. This is a great mistake. The only consideration that decides where the North shall be, is that all the ground to be sketched shall come into the paper: and as a matter of fact, it would very seldom do this if the top of the paper was

PLATE XXI.

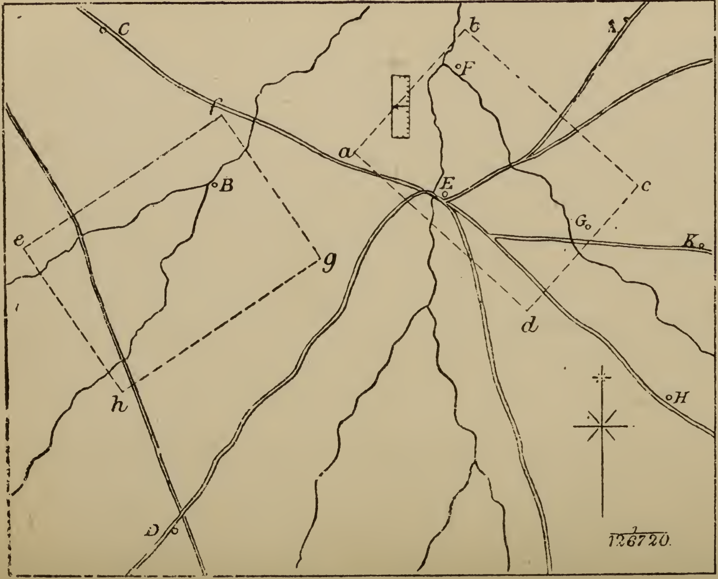
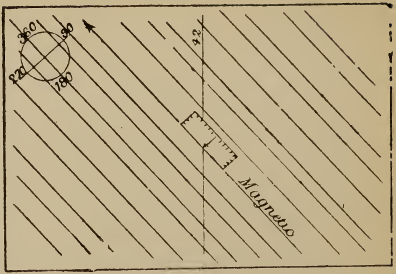


Fig. 1.

Fig. 2.



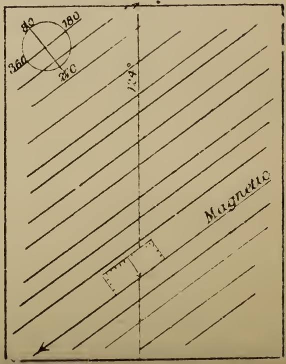


Fig. 3

invariably fixed on for the North. Therefore, before drawing magnetic meridians, we must determine a suitable direction for magnetic North upon our paper, and then, of course, the magnetic meridians are drawn parallel to it. We must then first consider : *What is the general direction in which we are going to sketch ?* This can be settled in a few minutes, either by an actual observation on the spot with the compass, or by reference to a map on which the ground to be sketched is indicated. The general direction being thus settled, a pencil line, representing this direction, is ruled straight up and down the centre of the sketching paper. The protractor is now laid anywhere on this line, the broad arrow touching it, and the graduated edge of the protractor uppermost, and the degree indicating the required direction coinciding with the pencil line. Then a line drawn along the inner edge of the protractor will be magnetic North and South, and other lines drawn over the paper, at irregular intervals, parallel to this, will be magnetic meridians by using which the whole sketch will fit comfortably on to the paper.

These instructions for drawing magnetic meridians for sketching, and the illustrations which follow, must be thoroughly understood. Simple as the matter is, innumerable mistakes are made about it : and I have constantly come across men who could sketch well enough when once started, but who were puzzled about the preparation of their paper with the necessary lines. Nothing is more vexatious than to find, long before it is finished, that your sketch is running off the paper : yet this is certain to happen unless the magnetic meridians are ruled in accordance with the principles above explained.

Examples. 1.—You are ordered to make a sketch of 3 or 4 square miles of country, the limits of your sketch being pointed out to you on a map of the district. Explain how you will prepare your paper. Draw a rectangular outline, *a b c d* on the map (*Plate XXI.*) defining those limits. Taking *a d* as the bottom of your sketch, you see at once that *the general direction* in which you are going to sketch is *a b*, or *d c*. You have, therefore, only to lay your protractor on either of these lines, with its inner edge parallel to the sides of the map, and you get its bearing, say 42°. Now you draw a pencil line straight up your paper (*Fig 2, Plate* XXI.) to represent this bearing ; lay your protractor on it, as before explained, so that it reads 42°, then draw a line along the inner edge of the protractor, and you have got your magnetic North and South ; and other lines drawn over the paper parallel to this one will be the magnetic meridians required, by using which all the ground to be sketched will fit on to your paper.

If a map of the district is not available, you must actually go to the ground which you are going to sketch, and with your compass observe the bearing of a point, which from your position represents the general direction in which you are going to work. Having got this bearing, you proceed as before with the preparation of your paper.

2.—You have to traverse the road C E H, (*Plate* XXI.) starting from C. Explain how the magnetic meridians should be drawn. The general direction of the road is ascertained (from the map or observations) to be 124°. A line is drawn straight up the sketching paper (*Fig. 3, Plate* XXI.) to represent this direction ; the protractor is laid on it, graduated edge uppermost, so that it reads 124°, and then a line is drawn along the inner edge of the protractor. This is magnetic North and South, and lines drawn over the paper parallel to it will be magnetic meridians, by using which the road throughout the traverse will be kept on the paper.

QUESTIONS FOR PRACTICE.

1.—You have to traverse a road of which the general direction is 180°. Prepare your paper with magnetic meridians.

2.—You are required to sketch the ground marked out in *Plate* XXI., by the letters *e f g h*. Explain how you would draw your magnetic meridians.

3.—The road C E K (*Plate* XXI.) is to be traversed, starting from C. Explain how you would draw the necessary magnetic meridians.

NOTE.—In the examples given which have reference to the map on *Plate* XXI., no allowance is made for magnetic variation. In short, it has been assumed that there is no variation; in other words, that the top of the map is Magnetic North, as well as true, or Geographical North. But generally there would be some variation, and it must be allowed for. That is to say, in laying the protractor on the map to see what is the bearing of any line on it, the edge of the protractor must be laid parallel to magnetic North and South; not (as was done in the examples quoted) parallel to the sides of the map, which generally represent approximate, true, or Geographical North.

4.—Referring to the map shown in *Plate* XXI., assume the variation to be 20° W, and then explain how you would draw magnetic meridians for a traverse of the road A E D, starting from A.

Resection * *with the Prismatic Compass.* — Resection is the process of finding your position on a sketch by taking the bearings of two or more points already laid down, and from them setting off bearings the exact opposite of those observed. The intersection of the lines thus drawn will exactly fix the observer's position. There is no operation more useful to the military sketcher than this, and he should constantly resort to it. With a few conspicuous points correctly fixed to start with, he has only to gallop to any spot at which there is work to be done, resect his position, and then quickly sketch in by eye all the details in his vicinity. It is remarkable how rapidly and correctly a large area may be sketched in this way. The principle of Resection with the compass rests on the fact, that if a point A is north of a point B, then B must be south of A;

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* Formerly spoken of as "Interpolation."

or if a point C is due west of a point D, then D must be due East of C : and so on. In other words, if the bearing of A from B is 360°, then the bearing of B from A must be the opposite of 360°, viz., 180° : and if C bears 270° from D, then D must bear from C just the opposite of 270°, viz., 90°, and so on. In short, whatever is the bearing from you to any object, the bearing from that object to you must be the exact opposite of it. The only question is : What *is* the opposite of any given bearing? The answer to this is, that if the given bearing is anything up to 180°, you must add 180° to it to get its opposite ; if it is above 180°, you must subtract 180° from it to get its opposite. Thus the opposite:—

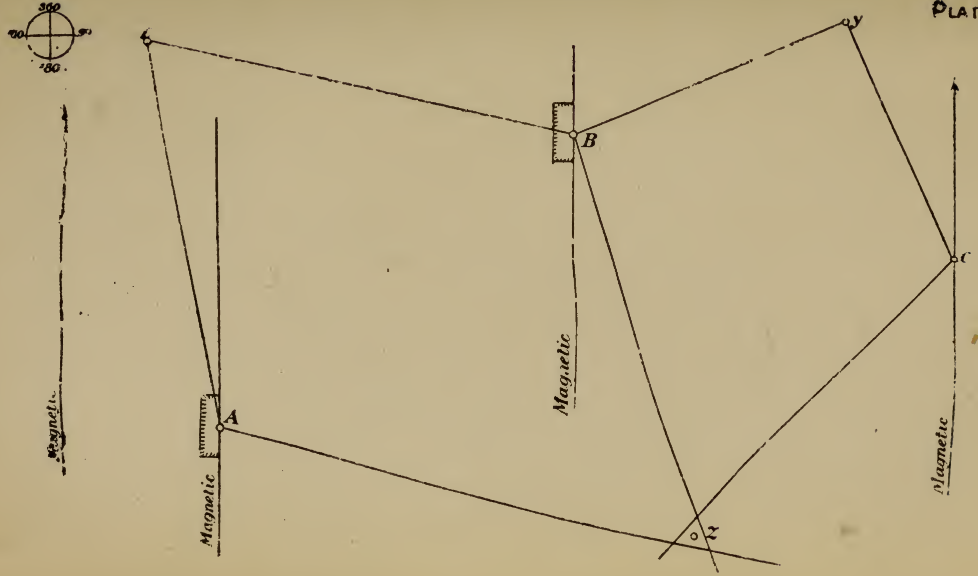
of 32° is 32° + 180° = 212°
„ 127° „ 127° + 180° = 307°
„ 183° „ 183° − 180° = 3°
„ 291° „ 291° − 180° = 111°

and so on. But as the sketching protractor previously described shows this clearly by the double row of figures along its graduated edge, even this small calculation is unnecessary. It should be noted that in seeking points by which to resect your position, those must be avoided which would give bad intersections : that is, intersections very acute, or very obtuse. Such intersections are unreliable. If a bad intersection is temporarily unavoidable, you should endeavour to check it as soon as possible by an observation from a third point.

If the bearings of *three* stations are taken, and the opposite bearings when protracted, instead of meeting (as they would if the work was perfect) in one point, form a triangle ; then in rapid sketching the error will be best distributed by the observer assuming his correct position to be in the centre of the figure thus formed, or the point of intersection of the two most correct bearings.

Examples. (*See Plate* XXII.)—A, B, C, are three points already laid down in a sketch. An observer wishing to

PLATE. XXII.



mark his own position at different times during his work takes the following bearings :—

$$\text{From } x \begin{cases} \text{to A, } 170^\circ \\ \text{to B, } 100\tfrac{1}{2}^\circ \end{cases}$$

$$\text{From } y \begin{cases} \text{to B, } 246\tfrac{1}{2}^\circ \\ \text{to C, } 155^\circ \end{cases}$$

$$\text{From } z \begin{cases} \text{to A, } 282^\circ \\ \text{to B, } 342^\circ \\ \text{to C, } \ \ 44^\circ \end{cases}$$

Find x, y, and z.

First to find x : The bearing *to* A being 170°, the bearing *from* A must be the opposite of 170°, viz., 350°. Consequently, the protractor is adjusted to the point A, its inner edge being exactly parallel to magnetic North and South, and its graduated edge turned to the left, and 350° is pricked off, and the line A x drawn. In the same way, *from* B is set off the opposite bearing to $100\frac{1}{2}$°, viz., $280\frac{1}{2}$°, and the line B x drawn. And the point x is thus found by the intersection of these two lines.

In a precisely similar manner, y is found by setting off *from* B and C, the opposite bearings to those observed.

But with regard to z, it is found in setting off from A, B, and C, the opposite bearings to those observed, that the lines drawn do not all meet in one point, but form a small triangle. There is, therefore, a small error somewhere, either in the observations made, or in the position of one of the points observed. It may be therefore assumed that z is about the centre of the triangle, and this would probably be quite accurate enough for *practical* purposes.

QUESTIONS FOR PRACTICE.

1.—Prick the points A B C (*Plate* XXII.) on to a sheet of paper, and then find x and y, the following bearings being given :

$$\text{From } x \begin{cases} \text{to A, } 278^\circ \\ \text{to C, } 347^\circ \end{cases}$$

$$\text{From } y \begin{cases} \text{to A, } 205^\circ \\ \text{to B, } 124^\circ \end{cases}$$

Taking the scale to be $\frac{1}{10560}$, give the distance from x to y, and the bearing of the line x y.

2.—From a point P, you observe the bearing of a point M to be 192°, and of another point N to be 97°. Assuming that N is 1,000 yards North-East of M, what is the shortest distance from P to the line M N ?

3.—A B C are three points forming a triangle. A B is 1120 yards, and the bearing of A from B is 220°. The bearing of C from A is 90°, and of B from C, 330°. Find C. From a point x, the bearing of B is 61°, and of C, 112°. Find x. And, finally, find y, and its distance from x ; the bearing of x from y being 260° and of C, 180. Scale, six inches to a mile, variation, *nil.*

THE VARIATION OF THE COMPASS.

Definition.—The variation of the compass (also spoken of as "the declination" of the compass) is the deviation of the needle from True North : or, in other words, is the angle between the direction of the needle and the direction of True North. The variation is said to be so many degrees East, or West, according as the needle points to the East or West of True North.

The variation or declination is subject to two principal variations—

Annual and *Positional.*

The *Annual Variation.*—In London, in 1576, it was 11° E. It then receded Northwards, and in 1660 the Magnetic and True North coincided. In 1814 the greatest West variation was recorded, 24° 20′. Since then the needle has been returning Northwards at the rate of about 7′ a year.

At the present time in England it is about 16° W ; in North India, about 2° 50′ E.

The *Positional Variation.*—The declination is different according to one's position on the earth's surface. As a general rule it is West in Europe and Africa and East in Asia and America.

There is also a slight diurnal irregularity in the movements of the needle, different in summer and in winter. In summer in England from sunrise till about mid-day, the needle moves Westwards about 15 minutes, then returns gradually to its original position about 10 p.m., where it remains till morning.

It has already been remarked that the variation is not the same in all compasses. Hence it is important that everyone should know the variation of his own compass; and that a sketch should be begun and finished with the same compass. This difference in variation is generally due to one of the following:—Needle not correctly fixed to card or incorrect centring of card.

Another peculiarity possessed by the magnetic needle is its tendency to point *downwards.* This is called "the dip" or "inclination" of the needle. It varies in all parts of the world. At the magnetic poles, it would be vertically downwards: about the Equator it would be imperceptible; in England it is about 70° N, and in South Africa about 55° S. Where the dip is noticeable, it should be counterbalanced by weighting the elevated end of the needle with a little sealing-wax.

On every sketch, provided the variation or declination is known, the direction of True North, *and* of magnetic North, should be clearly indicated by the proper conventional signs; the variation, however, should, if possible, be determined by other than approximate methods. True North is a direction which never changes; therefore, by showing it on every sketch, we get a line on each common to all, by reference to which sketches of adjacent bits of country executed by different officers (as in a combined survey) can be correctly pieced together; or compared with existing maps; or extended, or revised, at a subsequent period when the magnetic conditions may have altered.

To find the variation of the Compass.—We must first find the True North. Then take its bearing with the compass; if the bearing is 360°, of course the variation is *nil.* If the bearing is not 360°, then the variation is the number of degrees between 360° and the observed bearing; and it is East, or West, according as the needle points to the east or west of True North. We shall come to some examples of this directly.

The following are approximate methods of finding True North and should not be used to determine the magnetic variation or declination:—

(*a*). Attention is invited to *Plate* XXIII. In the diagrams there given, N is the North, or Pole Star (*Polaris*). P is the position of the Pole, *i.e.*, the direction of True North; and α, β, γ, δ, ϵ, ζ, η, are seven stars forming the constellation known as the Great Bear, (*Ursa Major*) *a*, *b*, are "the pointers," and point towards the North Star.

Now P, the Pole, is of course an invisible point; but as all the stars revolve round it, it is evident that twice in every 24 hours the north star, N, must come into the same vertical plane with it. Therefore, by taking the bearing of the north star when it is vertically above or below the pole, we are really taking the bearing of the pole itself, *i.e.*, of true north which is what we want. And to know when the north star is in the same vertical plane as the pole, we have only to take a plumb line, and ascertain when the star *Zeta*, ζ, is vertically above, or below it. When it is, then all three—the north star, the pole, and the star *Zeta*—are in the same vertical plane. The way then would be to plant a rod between the feet, and let an assistant plant another rod, carefully dressed on the north star by means of the plumb line, some distance away from you, the further off the better; but it would depend on the light. These two rods would then represent the direction of true north, and the bearing of one being taken from the other by day-light, the variation of the compass is at once ascertained.

It may be inconvenient to wait until the north star, and *Zeta* are in the same vertical plane. In that case, the operation above described may be carried out when *Zeta* is due east, or due west of the north star (*Figs.* 3 *and* 4, *Plate* XXIII.) But when these two stars are in the same horizontal plane, the difference in the bearings of the north star, and of the pole is 1° 27′. Therefore this amount must be added to the observed bearing if the observation is made when *Zeta* is to the east of the north star and subtracted if to the west. It is, perhaps, sufficient to know that in the Northern Hemisphere in ordinary latitudes the bearing of the Pole Star is always within 2° of True North.

PLATE XXIII.

Fig. 1.

Fig. 2.

Fig. 3.

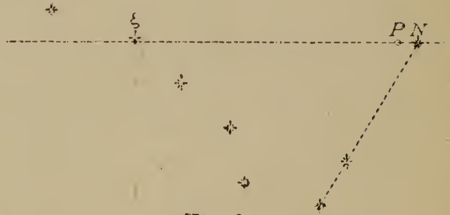


Fig. 4.

(*b*). In the Southern Hemisphere the Southern Cross is approximately South when its longest limb is vertical. At other times this constellation is about 30° distant from the Southern celestial pole.

(*c*). At the end of March and end of September the sun rises due East and sets due West.

(*d*). At noon the sun is on the meridian ; a pencil or pin stuck upright will cast an approximate True N and S line.

(*e*). By means of a watch. (*See page* 141).

(f). (*See Fig*. 30).—Lean a pole pointing northwards on two crossed sticks. From its tip drop a plumb line to the ground. From the point thus found as centre, and with any convenient radius, describe a circle. Before noon, watch the shadow of the pole as it gradually gets shorter and shorter

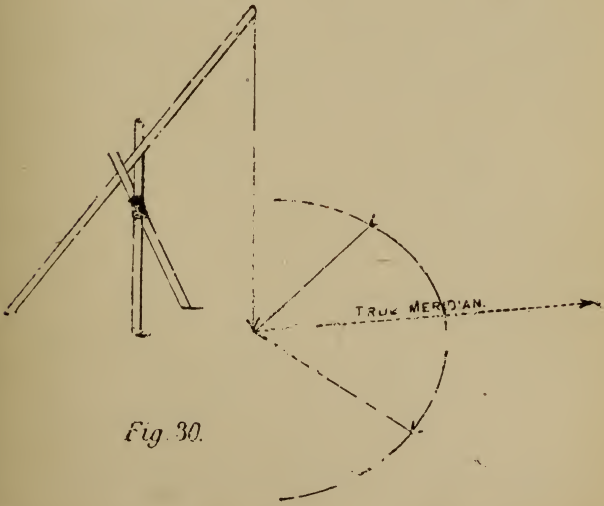


Fig. 30.

till at last the tip of the shadow will just touch the circumference of the circle. Mark this spot with a picket. After

12 o'clock the shadow will lengthen again. Watch it as it creeps out until again its tip just touches the circumference of the circle; mark this spot with another picket. Between these two observations, the sun must have culminated in the heavens; therefore, if the arc between the two pickets be bisected, and a line drawn from the centre of the circle to the point of bisection, the direction of the true meridian will be obtained. The ground on which this operation is carried out must be perfectly smooth and level.

How to find the variation of the Compass.—The direction of True North being known, to find the variation of the compass, a few examples will make this clear.

1.—The bearing of true north is observed to be 350°. What is the variation of the compass?

Describe a circle, and draw its vertical diameter to represent true north and south; write over the true north its observed bearing, 350°. Then it is evident that 360°, or magnetic north, will come 10° to the right of this: therefore the variation must be 10° east. (*Fig.* 31)

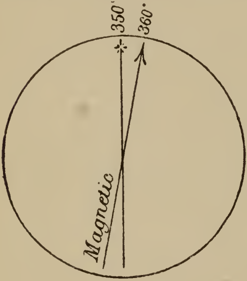


Fig. 31.

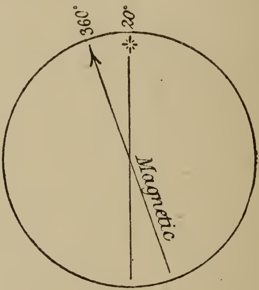


Fig. 32.

2.—The bearing of the pole star when on the meridian is 20°. What is the variation of the compass?

Answer, 20° west. This is evident from *Fig.* 32. As before a circle is described, and its vertical diameter drawn representing true north and south. This is marked with the observed bearing, viz., 20°, when it is immediately seen that the needle, or 360°, must be 20° to the left, and therefore the variation is 20° west.

This class of question appears to puzzle sometimes, but there is small likelihood of its doing so if it is answered on the lines indicated above. Nothing can be simpler. Describe a circle, and draw a line representing true north and south; write above this the observed bearing, then *see where the magnetic 360° falls.* This at once gives the variation, and shows whether it is east or west.

3.—The bearing of the pole star is observed to be 17° 3′ at the same time that the star *Zeta, Ursæ majoris,* is at the same altitude with, and east of it. What is the variation of the compass?

Here we know that we must add 1° 27′ to the observed bearing to get the correct bearing. Accordingly for the correct bearing of true north we have 18° 30′, and therefore, proceeding exactly as before (*See Fig.* 33), we see that the variation must be 18½° west.

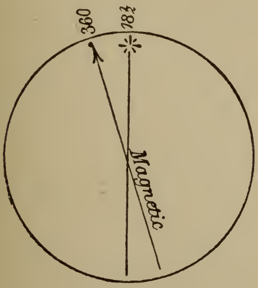


Fig. 33.

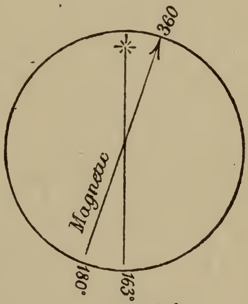


Fig. 34.

4.—The bearing of the sun when on the meridian is 163°. What is the variation of the compass?

In this case, the principle is exactly the same; but as it is the bearing of *True South* which has been observed, we write the observed bearing at the South end of our true meridian, and then see where our 180° will fall. As soon as that is settled, it is evident the other end of that line must be 360°. The difference between 163° and 180° is 17°, and *Fig.* 34 shows that the variation must be East. The answer, therefore, is 17° East.

QUESTIONS FOR PRACTICE.

1.—State what would be the variation of the Compass in each of the following cases:—

(*a*) When the bearing of the sun at noon is 193½°.

(*b*) When the bearing of the Pole Star on the meridian is 15° 45′.

(*c*) When the bearing of the Pole Star, taken at the time that ζ *Ursæ Majoris* is at the same altitude with, and due West of it, is 348° 7′.

2.—Explain how you would find the variation of your own compass.

3.—Define "variation of the compass": and state what you know concerning it.

4.—Why is it desirable that on all military sketches, True North, and Magnetic North, should both be shown?

5.—A sketch was made when the variation of the compass was 7° East. The same sketch is given to you some years afterwards to revise and extend, the variation now being 3° West. Explain what step you would take to ensure correct work.

To lay down the true and Magnetic Meridians on any Sketch.—It has already been stated why it is desirable that on all military sketches the true and magnetic meridians should both be shown. To lay them down on a sketch we must know the bearing of some line on it. The protractor is then laid on this line with its graduated edge in the direction of the given bearing, and giving the required reading. Then a line drawn along the inner edge of the protractor will be a magnetic meridian: and the variation being ascertained, True North can now be drawn, making the proper angle with it.

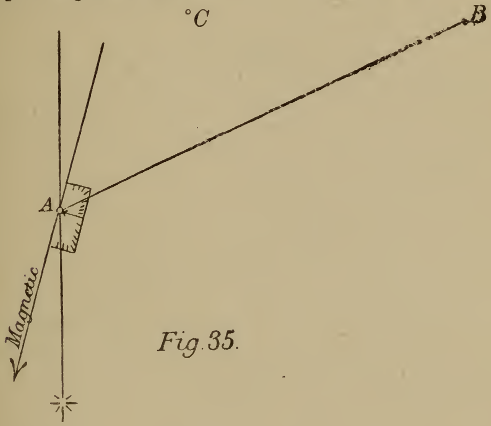


Fig. 35.

For instance, supposing this diagram, *Fig.* 35, to represent part of a sketch on which it is required to lay down the true and magnetic meridians. It is ascertained that the bearing of B from A is 230°, and that the variation is 15° East. A line is drawn joining A B: on this line (at *any* part of it) the protractor is adjusted so as to read 230°: then a line is drawn along its inner edge, and we have our magnetic meridian. Now we know the variation is 15° East; so if we draw another line making an angle of 15° with this one *to the left of it*, we get our true meridian. They should always be shown, as in this diagram, by the proper conventional signs.

QUESTIONS FOR PRACTICE.

The bearing of C from A in *Fig.* 35, being 297°, and the variation $18\frac{1}{2}°$ West, lay down true and magnetic meridians.

To fix the position of a point with the Prismatic Compass.—This may be done in three ways. The first is to take its bearing, and pace up to it. This is the method employed in traversing, work for which the compass is specially adapted. Thus, if we wish to sketch correctly the windings of the road A B C D, *Fig.* 36, we should start at A, take the bearing to the first bend B, and then pace the distance A B. This would fix the point B. We should then take a fresh bearing from B to the next bend C, pace up to it, and thus fix it; and so on.

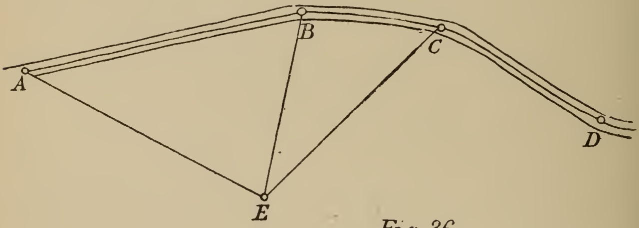


Fig. 36.

The next method of fixing a point is to take its bearing from both ends of a measured base, or from points already fixed. Thus, the point E in *Fig.* 36, could be correctly fixed by bearings taken to it from A and B, they being points already laid down. This is the ordinary method of fixing points when sketching a portion of country, and will be referred to again when speaking of Intersection. In the meantime, a caution previously given may be repeated here, that when fixing points in this way bad intersections must be guarded against. They are always unreliable. Thus, it would be quite wrong to try and fix the position of E in the above instance by bearings taken from B and C. The lines B E and C E meet at an angle much too acute.

PLATE XXIV

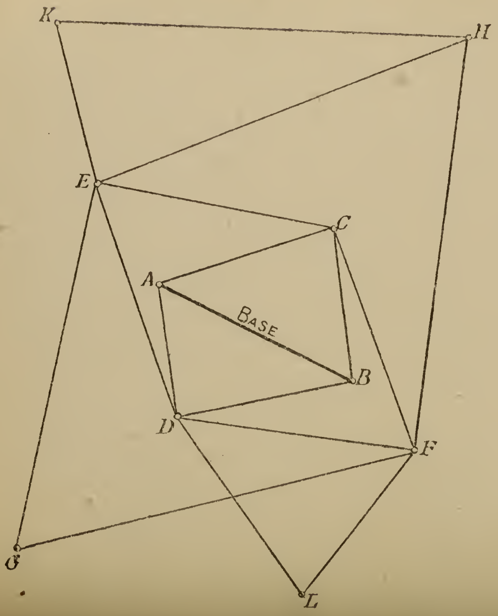


Fig 1.

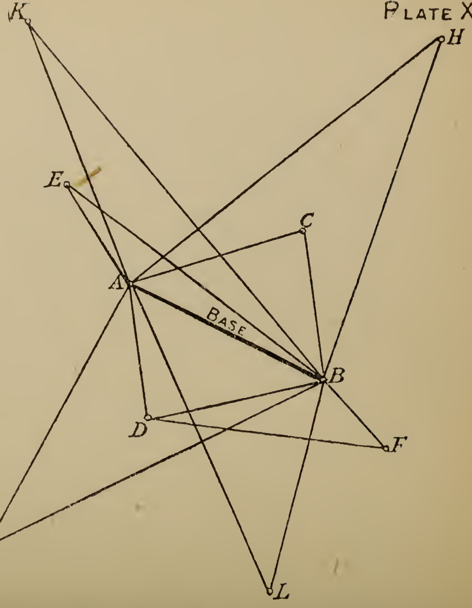


Fig. 2.

A third way of fixing the position of a point is by Resection. This process has already been fully described.

Intersection with the Prismatic Compass. — It has already been explained that if there is a choice of instruments, the Sextant, on account of its superior accuracy, is preferable to the compass for the work of Intersection. But the work *can* be done with a compass, and with accuracy sufficient for practical purposes, if care is taken in choosing stations, &c. Moreover, for one officer who possesses a Sextant, or knows anything about it, there are certainly fifty who own a Prismatic Compass, and are familiar with its use. Therefore, a few remarks are necessary on the method of Intersecting stations with this instrument. A base is first selected, carefully measured, and its bearing taken. It should be measured more than once when there is time, and its bearing should be taken from both ends. It is then plotted. The next step is to fix the position of important points over the ground to be sketched. This is commenced by taking bearings to them from both ends of the base. But it is a mistake, and a very common one with beginners, to try and fix too many stations by observations from the ends of the base. This invariably leads to a confusion of lines, and bad intersections. Compare *Figs.* 1 *and* 2, *Plate* XXIV. In each the same base, and the same stations are represented. But it is easy to see which is good work, and which is bad work. It is generally quite sufficient to fix one or two stations on each side of the base, by observations from its ends; and from them—as though from the ends of a new base—to fix more distant stations. In this way E and F (*Fig. 1, Plate XXIV.*) have been reliably fixed by observations from C and D: and in their turn, they are used as points of observation from which to determine the positions of H and G.

There is much more yet to be said about intersection of stations generally, but it will all be found fully treated of in a separate chapter. In this place we are simply concerned with describing the uses to which the Prismatic Compass may be put.

To measure, or lay off, an angle with the Prismatic Compass.—Angles can be measured, or laid off with the compass, although it is not generally used for these purposes, the sextant being much handier. But of course it can be done, for the difference in the bearings of any two objects is the angle between them. Thus suppose from A (*Fig.* 37) the bearing of B is 12°, and of C, 73° ; then the angle B A C must be 61° : again, if a right angle has to be laid off at C in the direction of D, we take the bearing of C A, and finding it to be 253°, we look out towards D for an object whose bearing is 163°, that is, 253°—163°=90°; this gives us the right angle required.

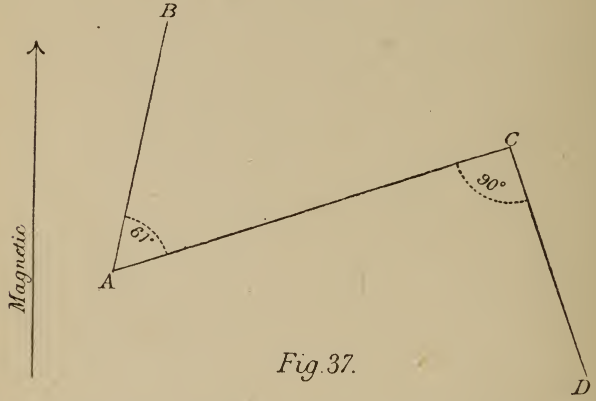


Fig. 37.

To measure a distance with the Prismatic Compass.— Select any convenient base, take its bearing, measure it, and plot it. Then from its ends take bearings to the object whose distance off is in question, and plot them. Their intersection will fix the object, and its distance can then be measured off the same scale that was used for plotting the base.

Example.—Required the width of the river at A B (*Fig.* 38)

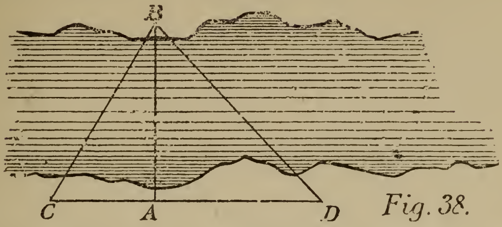


Fig. 38.

A convenient base C D is measured on the bank, and its bearing taken, and it is then plotted on some large scale. The bearings C B and D B are then taken and plotted, and B is thus fixed. The distance A B is then measured off the same scale that was used for plotting the base C D.

If the ground on the near bank is broken so that a base cannot be measured along it, the following expedient may be adopted. Produce B A indefinitely towards yourself. Set off A D at right angles to A B, and from any convenient point D, lay off the angle A D C equal to the angle A D B. Then A C, which can be measured, will be equal to A B. (*Fig.* 39.)

For example, suppose it is not convenient to measure a base on the bank. (*Fig.* 39.) We stand at A and take the bearing of

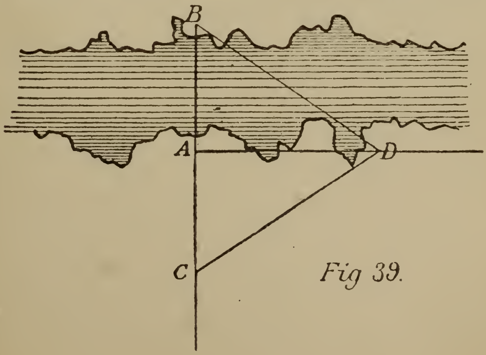


Fig 39.

B, and find it to be (say) 360°. We then turn round till we find an alignment A D, of which the bearing is 90°· This gives us the required right angle at A. Then we find some convenient point on this alignment, D, and taking the bearing D A (270°) and D B (302°) we see that the angle A D B must be 32°. Consequently we look for a point now in the alignment B A which will make an angle at D of 32° with D A. The bearing of this point must be 238° (270°—32°). In this way, the point C is found, and as the triangles D A C, D A B, are similar and equal, the side A C must be equal to the side A B.

Note.—This method is particularly adapted to the sextant.

SUMMARY OF THE PRISMATIC COMPASS.

(*a*) It is very portable and simple to use.

(*b*) It is specially adapted for traversing.

(*c*) It only requires two fixed points for resection, whereas with the Sextant three are necessary.

(*d*) Very useful to help you to find your way, or to keep your direction.

(*e*) Especially suitable for road and river reconnaissance, area sketching in thick country such as forests, flat ground covered with high grass.

On the other hand :—

(*a*) It is not a very accurate instrument.

(*b*) It is difficult to work with it in rough weather.

(*c*) It is untrustworthy in the neighbourhood of iron.

(*d*) Not so useful as plane table in fairly open country.

QUESTIONS FOR PRACTICE.

1.—Plot the following distances and bearings, scale $\frac{1}{10560}$.

A to B,	distance	570	yards,	bearing	68°
B to C,	,,	625	,,	,,	15½°
C to D,	,,	535	,,	,,	280°
D to E,	,,	480	,,	,,	227½°

As far as C the work was done with a compass, whose variation was 5° East. At C, another compass was taken into use, having no variation.

2.—Plot the following Intersection of stations, scale $\frac{1}{10560}$.

Base A B, bearing 69°, length 955 yards.

$$\text{A to}\begin{cases}\text{C—}120^\circ\\ \text{D— }33\tfrac{1}{2}^\circ\\ \text{E—}349^\circ\\ \text{H—}163\tfrac{1}{2}^\circ\end{cases}$$

$$\text{B to}\begin{cases}\text{F— }73^\circ\\ \text{K—}338^\circ\\ \text{D—}302^\circ\\ \text{E—}283\tfrac{1}{2}^\circ\\ \text{C—}187^\circ\end{cases}$$

$$\text{C to}\begin{cases}\text{H—}245\tfrac{1}{2}^\circ\\ \text{G—}268^\circ\end{cases}$$

$$\text{D to F— }90\tfrac{1}{2}^\circ$$

$$\text{E to}\begin{cases}\text{K— }48^\circ\\ \text{G—}196^\circ\end{cases}$$

$$\text{M to}\begin{cases}\text{H—}247\tfrac{1}{2}^\circ\\ \text{F—}20^\circ\end{cases}$$

$$\text{L to}\begin{cases}\text{D—}90^\circ\\ \text{G—}159^\circ\end{cases}$$

(*a*) What points in the above are found by Resection?

(*b*) Point out any bad work, giving reasons.

(*c*) Explain how you would check the accuracy of the work.

(*d*) Show true and magnetic north by the proper conventional signs, variation 18°, locality, near London.

3.—A B C are three points in a straight line, A B being $\frac{2}{3}$rds of A C. D is a point below this line, and the distance B D is $\frac{2}{3}$rds of A B. The angles A B D and C B D are respectively 80° and 100°, and the bearing of D from B is 240°.

(*a*) Give the bearing of the lines D A and D C.

(*b*) State the angles which D A and D C make with true North, the variation being 15° East.

4.—From a point A, the bearing of a point B, distant a quarter-of-a-mile, is 180°. From a point C, the bearing of A is 301°, and of B 229°. Show the position of C. The line A B subtends at a point D on the side opposite to C, an angle of 60°, and D A, D B are each 20 chains long. Give the distance and bearing from D to C. Scale 12 inches to a mile.

III.—THE PLANE TABLE.

There is only one serious drawback to the use of the Plane Table, and that is, that in its most portable form it is an awkward thing to carry about. Several light patterns of Plane Table have been invented, and good work has been done with some of them: but in the effort to make them light and portable, strength and stability are very apt to be unduly sacrificed. Notwithstanding, the Plane Table in any shape is a most valuable instrument. Compared with the Prismatic Compass it has many advantages. Its use is much more quickly learnt, and its operations are much quicker, and far more accurate. In accuracy, indeed, the work of a Plane Table approaches that of a Theodolite. This is because the directions laid down by its means are, so to speak, mechanically obtained. Col. Richards, Professor of Military Topography at the Staff College, says: "In using a Prismatic Compass and Protractor to lay down a bearing, there are at least *eight* sources of error. My experience is that from these the direction of a line cannot be depended on to within 30 minutes, under the most favourable circumstances, and when done by an experienced hand. But if the observer's eyesight be perfect, there is no source of error with the Plane Table in laying down *the direction* of lines." This is quite true. With a Prismatic Compass you have first to get the correct bearing—not always an easy thing to do if there happens to be any wind, or with a very sensitive needle—then you must remember it while you put away the compass, and get out the protractor: then the magnetic meridians ruled by yourself may not all be truly parallel, or you may not place your Protractor exactly parallel to them. Then the Protractor itself may not be correctly "centred," and in any case it is only graduated to show degrees, &c., &c.; so it is easy to see that there are many ways by which error may creep in. Whereas, with a

Plane Table the sights of the ruler are simply aligned on the object, a pencil line is drawn along it, and the thing is done, far more quickly and more accurately than is possible with a compass.

Another great advantage of the Plane Table is that though a Magnetic Compass is a most useful adjunct to it, still excellent work can be done with it without the aid of a compass. Consequently, in localities like South Africa, where owing to the great local attraction, the indications of a magnetic needle are untrustworthy, and an instrument like the Prismatic Compass becomes useless, valuable work can still be carried on with the Plane Table.

Description of the Plane Table, Sight-ruler or Alidade, and Box Compass.—One form of Plane Table consists of a smooth board about 16in. or 20in. square, which fits on the top of a tripod stand with folding legs, on which it can revolve freely. There is a screw underneath by which it can be firmly clamped in any desired position. A Sight-ruler or Alidade, and a Box-compass, are generally used with it, but any flat straight-edge (such as a marquois ruler) will do at a pinch, and any common compass can be used ; or sometimes the compass can be dispensed with altogether, as will be explained presently. However, the regular sight-ruler, and the box-compass, should be used when they are obtainable. The ruler is made of wood, or metal, and is flat with bevelled edges, and about 20 inches long. At each end of it are brass uprights, through which sights are taken. One of them, which may be called the backsight, has a fine slit down it to look through ; the other supports a horse-hair, and is exactly like the sight-vane of the Prismatic Compass. The body of the ruler should have various scales of yards, and other useful memoranda engraved on it. The sights of the ruler should be at least 6 inches high. In a hilly country where the line of sight is constantly at a considerable angle of elevation, or depression, this is a matter of some importance. The sights of rulers accompanying portable Plane Tables should be made to fold flat, and the hinges should be very strong. For use in hilly country a piece of cotton stretched taut from top to top of the sight vanes is useful.

The box-compass consists simply of a magnetic needle enclosed in a long narrow rectangular metal box, whose sides are parallel to the axis of the needle when it is pointing to Zero. These compasses are made of all sizes: a convenient one for carrying about is 6 inches long, in a mahogany box, with a sliding lid that throws the compass off its pivot.

The table above described would be much too heavy for ordinary sketching purposes. As before stated, several light patterns have been invented, and used with more or less success. In recent years the Mathematical Instrument Department in India have introduced one which has met with general approval. It is light, but very strong: the legs fold up so as to form a stout stick which can easily be carried in one hand, and the board can be slung on the back. Such a table could, no doubt, be carried anywhere, even on service. It does not take a minute to put together, or to take to pieces. There are several other patterns which can be obtained from the Ordnance Department, of which the Service portable, 18in. × 18in., with camera legs, is about the most useful.

To use the Plane Table.—Set it up at the spot selected for commencing work, and level it carefully. In setting it up attention should be paid to the following points:—

(*a*) See that the legs are rigid if they are a folding pattern.

(*b*) Legs should be well spread and pressed firmly into soft ground.

(*c*) The board must be level.

(*d*) See that it is set up exactly over the spot you are at, unless resecting your position.

To ensure theoretical accuracy, the point on the ground, and the point representing it on the paper, should be in the same vertical line. Now revolve the table, which all this time is unclamped, until you have got it into just the position you want with reference to the position of your starting point, and the direction in which you are going to work. In short, take care so as to arrange that the whole of your sketch will come on to the paper. This being satisfactorily settled, mark your starting-point on the paper and clamp the table. Some sketchers use a pin for marking the position. If you do, a fine needle with a lump of sealing-wax on the end is better than a pin as it does not make so big a hole. Now take the compass: lay it somewhere near the edge of the paper, and move it about till you get the needle to point exactly to North. Then draw a pencil line along it, and mark the North end of this line with an arrow head, and write "magnetic" on the tail. The compass can then be taken up and put away for the present. This line that you have drawn will be the *zero line* of your sketch, and it is evident that at any subsequent period in your work you can by reference to it "set" the Table correctly. ("*Setting*" the table means placing it in a position parallel to its original position, and, therefore, in a correct position with regard to surrounding objects. In other words, when a Table is "*set*," every line on the sketch will be parallel to its corresponding line on the ground). We are now ready to commence work. Take the ruler and place it against the pin, or your pencil if a pin is not used, and which should be held upright with its point against the ruler. Align the sights on any object whose direction is required: draw a line along the edge of the ruler, and the thing is done. It is unnecessary to draw lines the whole way from the starting point. For instance, you take a *ray* to a chimney, which is about 700 yards away, a line for the first 600 yards is not wanted and only tends to cover the sketch with useless marks. Again, in drawing short rays, their prolongation should be marked on the margin of the sketch by a short line. These are called "repere" marks and are useful as they give a good line to lay the ruler on. In this way, by directing the ruler in succession at various objects, their direction is rapidly and accurately fixed. The Table is now taken up and carried to the next station. Let us suppose the first station was A, one end of a selected and measured base, *Fig.* 40, and that rays have been taken to B, C, D, and E. We now put up the Table at B, stick the pin into the point representing it on paper, and proceed to

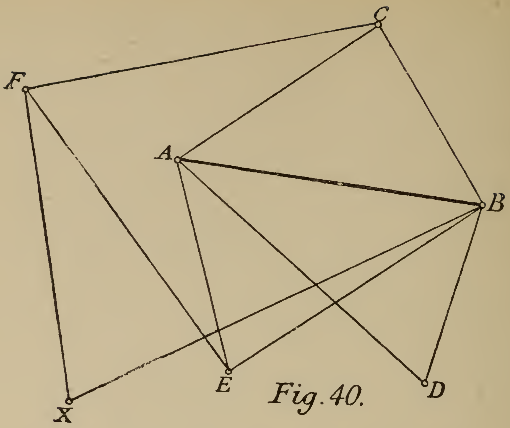


Fig. 40.

"set" the Table. This may be done *independently of the compass* in the following way :—Lay the ruler exactly along the line A B: unclamp the Table, and revolve it steadily till the sights are correctly aligned on A. Then clamp it. The table is now "set"; but as a check on its correctness, take the compass out, lay it on the zero line, and see if the needle points, as it ought to, to North. Of course, the Table can be "set" at once by the needle if preferred; but it is better to try to be independent of the compass, and to work chiefly by the back angle, using the compass only occasionally as a check.

Having now got the table "set," we have only to proceed with our observations. The ruler is placed against the pin, and rays taken to C, D, and E. These, if common care has been taken, will fix the position of those stations with absolute accuracy. Our next station would probably be E. Here the table is "set" by reference to the line E B or E A (the longest lines are the best), and checked again if considered necessary by the compass: then rays are taken to various objects, and the ground in the vicinity can at the same time be sketched in by eye, to save having to visit it again. And so the work proceeds. Attention is called to p. 79, which applies equally to Plane Table work.

It may be noted here that every time you "set" the table, you compare your sketch, and the position and distance of objects on it, with the actual ground. You cannot well help doing so, if you want to satisfy yourself as you proceed with the general correctness of your work; and consequently any error that is made is almost sure to be detected at once. This by itself is a great advantage; but this habit which is engendered by "Plane-tabling" of constantly comparing one's work with the ground, is doubtless a greater one. It is a great aid to a quick and intelligent appreciation of the features of a country, and better helps to make a man a good judge of distance (a quality invaluable to the military sketcher) than anything I know.

It has been stated that as a rule it is a good plan to "set" the table by the back angle, and only to use the compass occasionally as a check. This rule does not, however, apply to traversing. Here it would not be altogether safe to rely on the back angle, unless the stations were few, and the lines between them long; or unless there were some triangulated points *en route* available for purposes of check. Because when traversing by the back angle, a small error, being multiplied as you proceed, soon becomes a great one; whereas if the table is "set" by the compass at each station, each forward ray will be independent of the last, and then, even if a mistake is made, it certainly is perpetuated, but it does not increase as the work proceeds. The subjoined diagram, *Fig.* 41, shows this clearly. Therefore, in traversing with a Plane Table, use the compass constantly to "set" the table, and use it altogether if you are working through a thick country, or following a very winding line.

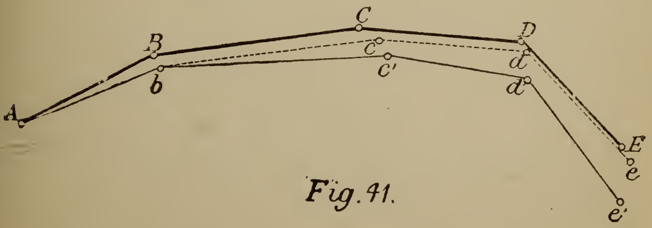


Fig. 41.

In this diagram A B C D E represents the *correct* traverse of a road. A *b c d e* represents the traverse made by a man Plane-tabling with a compass (or working with a Prismatic Compass) and A *b c′ d′ e′* represents the work of a man Plane-tabling, but relying on the back angle only to "set" his table. It will be seen that both made the same mistake at starting, and plotted A *b* instead of A B. After this no more mistakes were made ; but in the one case, as each observation is independent of those preceding it, the table being set by the compass, the original error, though perpetuated, does not increase, and the total error is small. In the other, as each fresh forward direction is fixed by reference to the one preceding it, the original error increases throughout the traverse, and the total error is a very serious one. And, of course, the longer the traverse, and the more numerous the stations, the greater immediate difference in favour of the compass. If E had been fixed by interpolation the traverse could be adjusted to close on E's correct position.

Resection with the Plane Table.—This is a most simple operation if a compass is available by which to "set" the table, and then requires only two fixed points. Without a compass, it may not be quite so simple, and *three* fixed points are necessary.

The various methods in which Resection may be effected are given below.

1.—*The Compass, and two fixed points, being available.*—The two fixed points are F and B (*Fig.* 40) and the point to be interpolated is x. "Set" the table by adjusting the compass to the zero line, and *revolving the table* till the needle points to North. Then clamp it. Stick the pin into F, or hold the pencil upright at that point, and placing the ruler against it, align the sights on F in the distance, and now draw a ray towards yourself. Transfer the pin to B and in the same way, get another ray from B towards yourself. The intersection of these two rays fixes your position x.

2.—*Three fixed points being available, but no compass* : or, when owing to local attraction, the compass is not to be relied on.

PLATE XXV

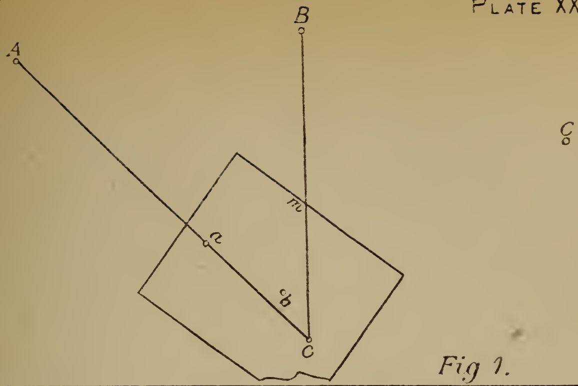


Fig 1.

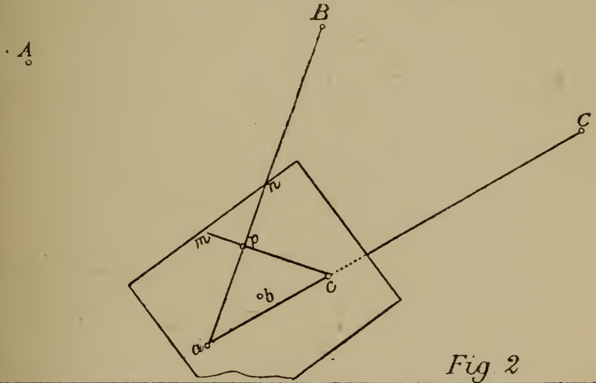


Fig 2

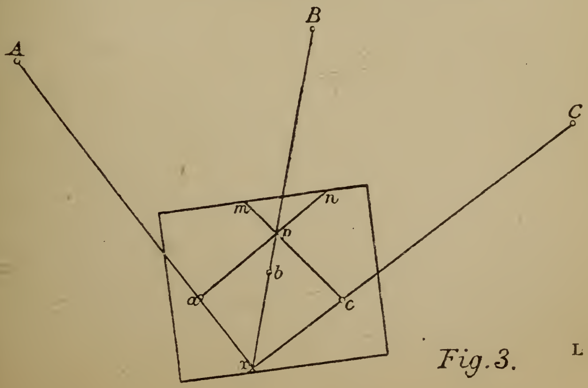


Fig.3.

L

PLATE XXVI

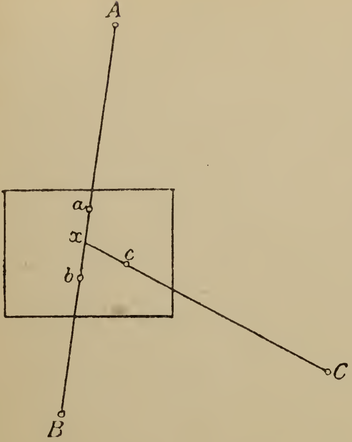


Fig. 1.

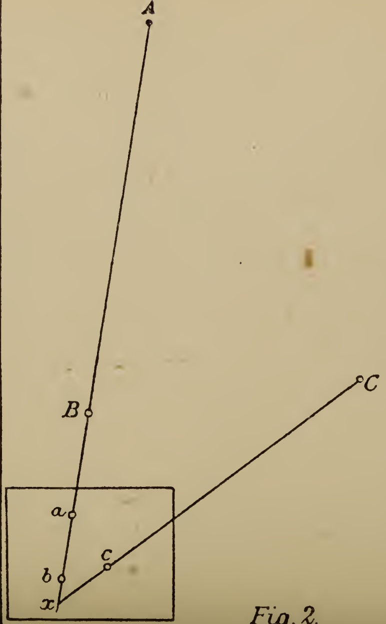


Fig. 2.

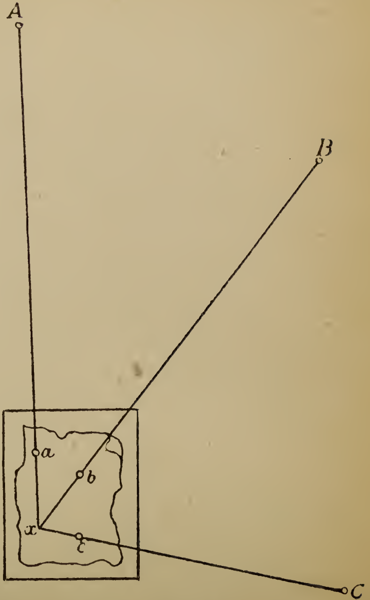


Fig. 3.

Let A B C (*Figs.* 1, 2, 3, *Plate* XXV.) be the three fixed points, represented on paper by *a*, *b*, *c*. It is required to find *x*. Here the difficulty is, having no compass, and no back angle to refer to, to "set" the table. This is how it may be done. Set up the table, and level it as usual. Adjust the ruler to the line *a c*, then revolve the table till the sights are aligned on A, *Fig.* 1, then from *c* take a ray to B. Call this *c m*. Now, again adjust the ruler to the line *a c*, and revolve the table till the sights are aligned on C, *Fig.* 2, then from *a* take another ray to B, call this *a n*, and the point where the rays *c m*, *a n*, intersect, call *p*. Now adjust the ruler to the line *b p*, and revolve the table till the sights are aligned on B. The table is now "set," and *x* can be interpolated in the usual way by rays from A and C, *Fig.* 3.

This method might prove useful on some occasions, but as its success depends chiefly on the length of the line *b p*, it could never be relied on to give more than the *approximate* position of *x*.

3.—It may happen that the points A B C are so situated that you can place yourself between two of them, (*Fig.* 1., *Plate* XXVI.) and "set" the table by the alignment so obtainable. Then a ray from the third point will fix your position. To align yourself exactly between two distant points, lay the ruler on the table, and sight them alternately from opposite ends of the ruler, moving the table bodily to the right or left, until they are both correctly sighted when viewed from either end of the ruler.

4.—Or, it may happen that with the same points A B C, you can place yourself in the prolongation of two of them, (*Fig.* 2, *Plate* XXVI.) and then "setting" the table by reference to the alignment thus gained, a ray from the third point, will as before intersect your position.

5.—The Tracing Paper method, called "finding the place by adjustment," and described at page 65 in the chapter relating to the sextant, is applicable also to the Plane Table. Fasten a piece of tracing paper over the sketch, and from *any* assumed point on it, *x*, take rays to A B and C. Then take up the tracing paper, and, applying it to the sketch, move it about till the lines x A, x B, x C, pass each through its corresponding station a, b, and c on the sketch. The position of x can then be pricked through, and the table can then be "set" by adjusting the ruler to any one of the lines x a, x b, or x c, and revolving the table till the station selected is correctly sighted. (*Fig.* 3, *Plate* XXVI.)

6.—Another way in which a point may be fixed, without using the compass, but it is not strictly Resection. It is, however, very useful, and constantly resorted to in practice.

A and B, *Fig.* 42, are two points already laid down on your sketch: you, being at B, find you have some work to do out in the direction of x, and when you get there it will be necessary to fix your position. You have no needle to help you.

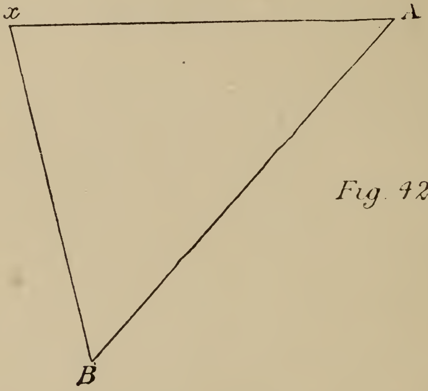


Fig. 42.

"Set" the table at B by the back angle B A, then clamp it, and take a ray to x. Now proceed in the direction B x till you have reached the point you want; then "set" the table by the back angle x B, and then a ray from A will fix your position. This method, and Nos. 3, 4, and 5, are all likely to be useful in eye sketching.

7.—*Interpolation* or fixing by resection from three known points, using the compass to roughly orient the table. It is the best method of resection and is as follows:—

Take three well fixed points, two fairly near and one distant.

i. Orient the table roughly with the compass.

ii. Draw back rays from the three fixed points.

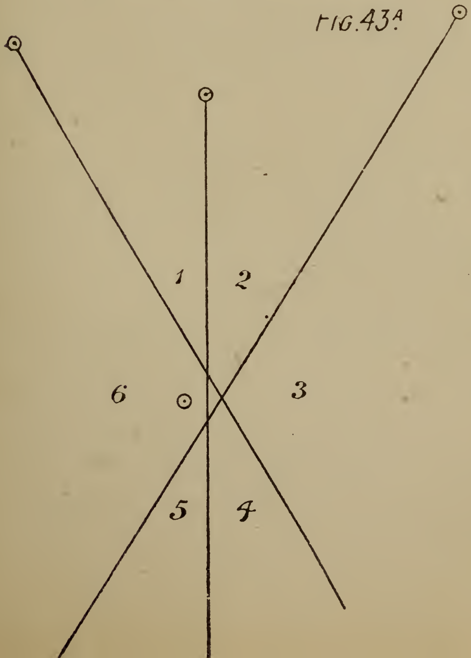
iii. If these rays meet in a point, that point is your position. If they do not, a small triangle called the "triangle of error" will be formed.

When a triangle is formed, find the true position as follows:—

(*a*) If the "triangle of error" is inside the triangle formed by the three fixed points, the position is inside the triangle of error; if not, it is outside the triangle of error.

(*b*) In the latter case, the position, when facing the fixed points, is either to the left of all the rays or to the right of them. Of the six sections (*Fig.* 43*a*) formed by the rays there are only two, 3 and 6, in which this condition can be fulfilled.

FIG. 43A.



(*c*) The exact position depends on the fact that its distances from the rays must be proportional to the length of the rays.

Example.—Where must one's position be in *Fig.* 43*a* ?

By (*a*). It must be outside the "triangle of error."

By (*b*). It must be in sector 3 or 6.

By (*c*). It must be in sector 6, the distances from it to the rays being proportional to the lengths of the rays, and by estimation it is where shown.

Having got your point, "set" the table by the farthest point and test its accuracy by the nearer points. If there is still an error go through the process again.

The best position is inside the triangle formed by the three fixed points as this saves (*b*).

The method fails when the observer's position and the three fixed points are on or near the circumference of a circle.

It is important to note the compass is only used for roughly orienting the table, and the final fixing does not at all depend on it.

To measure a distance, say the width of a river, with the Plane Table. Set up the table at any convenient spot, A, on the bank, *Fig.* 43, and clamp it. Mark *a* on your paper to represent this spot ; then take rays from *a* to B some mark on the opposite bank ; and to C, any conveniently situated mark on your own bank. Pace up to C, and having got the

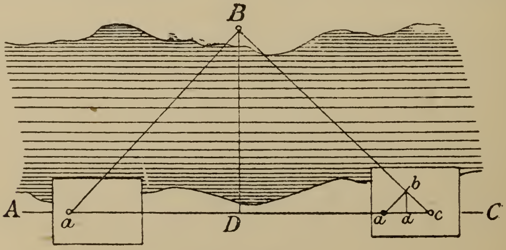


Fig. 43.

distance, plot it to some large scale. Now put up the table at C, and "set" it by reference to the line C A. Then take another ray to B, and by its intersection with the ray A B, B is fixed, and the width of the river, B D, can now be taken off the same scale that was used for plotting *a c*.

SUMMARY OF THE PLANE TABLE.

(*a*) It is a much simpler instrument to manipulate than the Prismatic Compass, and consequently its use is much more readily learnt.

(*b*) It is far more accurate, and far quicker in its operations, than a Prismatic Compass.

(*c*) It gives you a comfortable table to draw on in the field. This is no slight advantage.

(*d*) Its use engenders a habit of constantly comparing the sketch with the ground; and this is undoubtedly a valuable aid towards becoming a good judge of distance, and in training one to intelligently appreciate features of ground, and the general lie of the country.

(*e*) Valuable work can be carried out with it in localities where, owing to local attraction, a magnetic instrument would be useless.

Its one disadvantage has already been pointed out, viz., that it is an awkward thing to carry about. It is, however, right to say that officers of great experience, who used the Plane Table on service in Bhootan, Afghanistan, and other places, strongly prefer it, under most circumstances, to the Prismatic Compass: and are unanimous in their opinion that they never felt at any disadvantage from its want of portability.

INSTRUMENTS AND THEIR USES EXPLAINED.

IV.—THE CLINOMETER.

The Clinometer is an instrument for measuring vertical angles. By its means we can measure the angle that any slope makes with a horizontal line. We can also use it as a rough kind of level, as will be explained directly. The simplest form of Clinometer is the Protractor, with a string and plummet attached to it at the broad arrow marking the centre of its inner edge. (*Fig.* 44). It is evident that if it

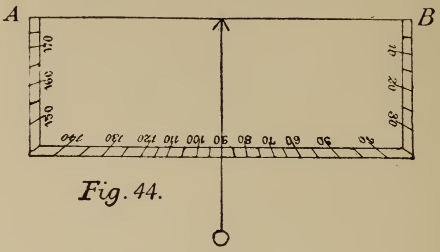
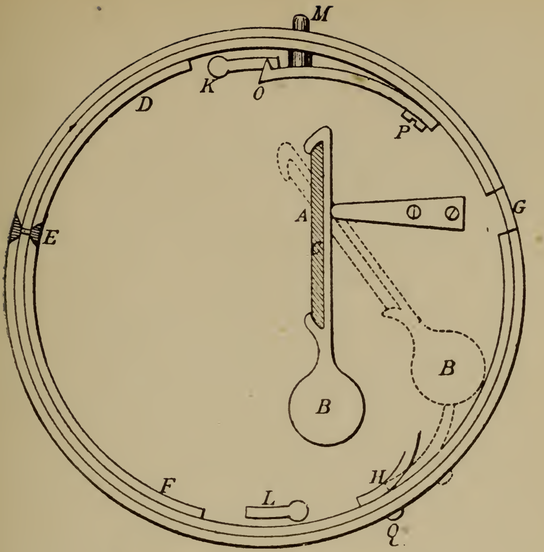


Fig. 44.

is held, as shown in the figure, with the plummet hanging vertically, and cutting the degree marked 90°, the edge A B must be horizontal: therefore, if we hold it so, and look along it, we can find distant points on a hill-side on the same level as that we are standing on. This is a matter of some importance when sketching hills, as will be seen later on. If we want to measure a slope, we depress (or elevate) A B till we judge it to be parallel to the slope, at the same time taking care to let the plummet swing freely. When it is steady, a finger is pressed against the string, and the degrees counted from the string to the 90° will be the slope.

A Clinometer of this kind is difficult to use in windy weather, as the string and plummet get blown about so much that the observations made would be hardly reliable. To obviate this defect, a little instrument has been invented by Col. Watkin, R.A., which is known now as the Watkin Clinometer. It is shown in *Fig.* 45, with its cover removed. D E F is a piece of ivory with a scale of degrees engraved on it. A B is a pendulum, carrying a mirror C, which reflects these degrees to the eye of the observer at E, the object observed being seen at the same time, past one side of the mirror, through the opening at G. In observing a slope, the line of sight must of course be parallel to the surface of the ground. If a point is wanted on the same level as the observer, the aim must be raised, or depressed,



THE WATKIN CLINOMETER

Fig 45.

until an object is found whose reading is 0°. H is a metal arm used to lock the pendulum B (see the dotted lines) and prevent it from swinging about when the instrument is not in use. Two slots, K and L, are slots cut into its base to enable it to be fastened to, and carried under a Prismatic Compass.*

The Abney Level is a very handy instrument for measuring slopes, much finer readings being obtainable than with the ordinary clinometer. There are several patterns, one pattern consists of a hollow rectangular tube *a b*, 4 to 5 inches long (*Fig.* 45*a*), having an eye piece *c* at one end, and inside the end is placed an inner tube *d*, about 1 inch long, the other end nearest *c* cut away at an angle of 45° and silvered with a horizontal hair line midway. In *a b* is a

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* There is a later pattern of Watkin Clinometer than the one figured above. The mirror is stationary, and the ivory arc with the scale of degrees swings. The princip'e, however, is the same.

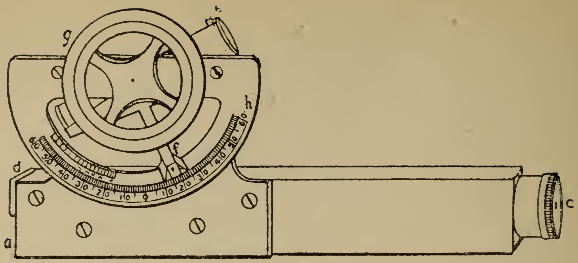


Fig. 45a.

slot which allows the observer looking through *c* to see the bubble reflected when in the centre of the spirit level.

A spirit level *e* is attached to an index arm *f*, and both are moved by means of a milled wheel *g*. The index arm moves over a graduated arc *h*. The instrument is so adjusted that an observer looking at an object level with him will notice the horizontal line cuts the centre of the bubble, and the arrow on the index arm points to zero.

The graduated arc is divided into degrees, and on the index arm is a vernier reading to 10 minutes.

Slopes from $\frac{1}{1}$ to $\frac{1}{10}$ are also marked on the arc. In using this scale the edge of the index arm furthest from the eye, not the arrow, must be on the line for the required slope.

To take an observation.—Hold the instrument in the right hand, and, looking through the eye piece, get the object and hair line in one horizontal line, and then gently moving the milled wheel *g* make the bubble cut the hair line. The elevation or depression is read off the arc by the arrow on the index arm.

THE ANEROID BAROMETER.

The aneroid barometer consists of a small flat cylindrical box from which nearly all the air has been exhausted. The top of the box, which is of thin metal, and corrugated to make it more sensitive, is elastic, and would collapse under the pressure of the external air if it were not supported by a flat spring, with which it is connected at its centre by a pillar. When the pressure of the air increases, the top of the box is pressed in; and when it diminishes it rises; and by means of two levers, these movements are communicated to a pointer, which moves round a dial on which is marked a scale of inches graduated by comparison with a standard barometer. The whole of this arrangement is enclosed in a strong outer case, exactly resembling a large watch. Besides the usual scale of inches, some aneroids have a scale of heights up to 20,000 feet, engraved on a moveable arc, which can be set at zero just before commencing operations. This is a very useful arrangement, and greatly increases the value of the instrument for surveying purposes. But if a scale of feet is not shown on it, then the difference in height between two stations may be calculated *approximately* from the following formulæ:—

$$H = \frac{52500 \times D}{S}$$

Where H is the height in feet of one station above the other. Where S is the sum of the readings of the aneroid at each station. Where D is the difference of the readings of the aneroid at each station.

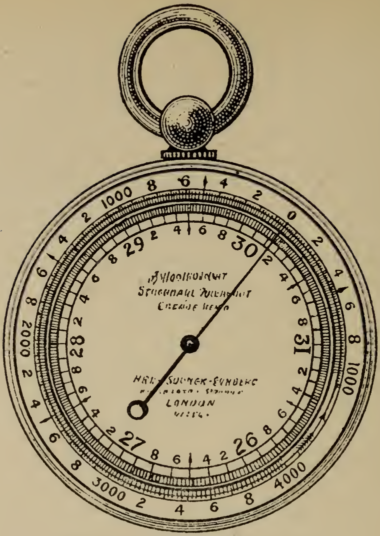
A more accurate one, which can be used up to 10,000 feet, without producing an error of more than 2 or 3 feet, is:—

$$S : D \left\{1 + \tfrac{1}{3}\left(\frac{D}{S}\right)^2\right\} :: 52,500 : H.$$

It is a useful instrument, especially when sketching on a scale of 1 inch to 1 mile and under, where contours with vertical intervals of 50 feet and upwards have to be recorded.

For military sketching there should be a moveable scale of heights in feet. A useful pattern aneroid is a $2\frac{1}{2}$ inch one reading to about 6,000 feet.

No good results can be expected in unsettled weather.



ANEROID BAROMETER.
Fig. 45b.

Before commencing work for the day, the barometer should be set to the height of the starting point; if this is not known to an assumed height, and, if possible, the same spot should be re-visited on completion of work and a reading taken. In case of any difference between the first setting and final reading, a proportionate allowance must be made for the intermediate heights according to the time which has elapsed.

V.—THE CHAIN, PACING, JUDGING DISTANCES, &c.

From what has already been explained about the different instruments used for Military Sketching, and the methods of using them, it will be seen that after every precaution has been taken that experience can suggest, one great source of error still remains, which must affect in some degree the accuracy of our work. It is the extreme difficulty of measuring with great exactness any given line, even that most important of all lines, the Base line. The time and means at the disposal of an officer do not, as a rule, admit of accurate measurements being made. His work in the field has generally to be done against time, and probably single-handed. Sometimes, indeed, it has all to be done on horseback. Under these circumstances it would be obviously impossible to measure a base, for instance, with that nicety which is desirable. Yet, for the execution of a sketch, however rough, some fixed points, and, therefore, some measurements, are absolutely necessary; and, of course, the more accurate they are, the better will be the work which depends upon them. Therefore, seeing the importance of the matter, and knowing that the time and means for making any measurement must always be extremely limited, it is all the more necessary that every officer should strive at his leisure to perfect himself in those methods of estimating distances which are always at his disposal, that he may resort to them with confidence when obliged to put them to the test. These methods are :

1.—The use of the chain, tape, &c.

2.—Pacing, and the use of the Pedometer.

3.—Cyclometer and Perambulator or Odometer.

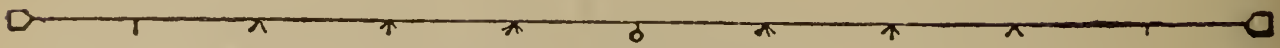
4.—Comparison of his horse's pace at a walk, trot, &c., with a measured distance : or with *the time* that he may take in going from one point to another.

5.—Judging distances.

6.—Estimating distances by the time taken in the transmission of sound.

7.—The use of the Range-finders.

1.—*The Chain* is used only in connection with *surveying* (not sketching operations) for instance, when an extensive triangulation with the sextant, or theodolite, is to be observed. It is known as "Gunter's Chain," and, including the handles, is 22 yards long, the distance between the wickets at cricket. 100 links make 1 chain, and when the chain is used, the measurements are always counted by links, not by chains Thus, if a base is found to measure just 30 chains, we should speak of it as 3000 links, not 30 chains. To bring links to yards, multiply by 22, and divide by 100. Thus, 3000 links $= \frac{3000 \times 22}{100} = 660$ yards.



GUNTER'S CHAIN.

Fig. 96.

At each 10 links in the chain, from both ends to the centre, there is a brass label with one, two, three, or four tongues. The centre is marked by a round label. This arrangement facilitates quick counting.

To use the Chain.—Two persons, called *the leader* and *the follower*, are necessary, and they should be supervised by a third. The leader takes one end of the chain, and ten iron arrows, and walks in the required direction. The follower holding the other end of the chain, halts him, dresses him exactly on the point to which they are measuring, and sees the chain is laid on the ground, straight in the required alignment, and free from knots, &c. The *outside* of the follower's handle must just touch the starting point. The leader sticks an arrow into the ground, just *inside* of his handle. It is as well for him to make a scratch on the ground too, to mark the spot, as the arrow may be accidentally knocked out. He then calls out "all right," gives the chain a cast to one side to clear the arrow, and goes on. The follower will take up each arrow as he comes to it, when the leader calls out "all right," showing that his point is marked, and that he is ready to start again. When the follower has collected the ten arrows, then 10 chains, or 1000 links have been measured, and are noted in the Field-book. He now walks up to the leader, and gives him back his ten arrows. The leader plants one at the spot he is standing at, calls out "all right," and goes on: and so the work proceeds. The total distance eventually measured will be 1000 links for every time the arrows have changed hands, *plus* 100 links for every arrow in the follower's possession at the end of the work (including the one marking his end of the chain), *plus* the odd number of links counted on the chain up to the end of the measurement.

Chaining is a very simple business, but requires attention while it is being carried out. The length of the chain is liable to alteration from strains, bends, &c., so it should be tested occasionally with some standard.

Other chains are Ramsden's steel chains, 100 feet and 50 feet long, divided into links 1 foot long.

Tapes are either steel or linen, and made in 100 feet and 50 feet lengths, divided into feet and inches, or feet and tenths of feet.

They are very portable, but the steel ones are very liable to kink and break unless carefully handled, and the linen apt to contract and expand.

2.—*Pacing* must in most cases be the Military Sketcher's main reliance, and therefore everyone should know exactly the length of his own pace, and be able to measure any given line by this means with confidence. The regulation military pace is 30 inches; but an ordinary walking pace is probably longer than this; and, in any case, if left to themselves, no two men would pace exactly alike. Everyone has a natural gait of his own, and should keep to it, for the attempt to step a longer, or a shorter pace, than one is accustomed to, is sure to result in fatigue, and then the pacing becomes unreliable. The best plan, then, is to pace several times, walking at your usual pace, a measured distance of 200 or 300 yards. You will thus ascertain pretty accurately how many of your paces go to one hundred yards; and *this is what you ought to know.* You can then, before you commence work, make for yourself a scale of paces comparative to the scale of the sketch (*See Chapter* I., *Comparative Scales, Example* 1). When actually engaged in pacing, a score should be made on a bit of paper, or on the shirt cuff, for every hundred yards, or hundred paces measured. Without this precaution vexatious mistakes in counting will be constantly made.

The Pedometer is a little instrument like a watch, which carried in the waistcoat pocket, mechanically registers every step taken by the pedestrian, and thus shows at any moment the distance he has traversed. These little instruments are wonderfully accurate, when once regulated to suit the step of the person using them, and where long distances have to be measured along fairly level roads, they will be found extremely useful. Full instructions for using and regulating them, are always given with them.

3.—A *Cyclometer* is a small instrument attached to bicycles, and registers miles, ½, ¼ and ⅛ miles, and even revolutions of the wheel. It is most useful, very accurate, and saves time and worry. One must remember the last distance measured by the instrument and subtract it from that now shown, to find how far two points are apart.

A *Perambulator*, or *Odometer*, is a useful instrument, especially when distances have to be measured along roads in an unsurveyed country. It consists of a large wheel of known circumference, attached to a frame, like the handle and frame of the front wheel of a bicycle. On the handle is a dial which is connected with the large wheel and which registers the distance travelled.

Another accurate method is to tie something on to the spoke of a cart or bicycle and count the revolutions. The number of revolutions, multiplied by the circumference of the wheel, is the distance. To measure the circumference, starting with the marked spoke downwards, revolve the wheel along the ground till the same spoke is again down, and measure the distance between the points marked.

4.—*To know the number of steps or strides* that his horse takes, when moving at a walk, canter, &c., over a measured distance, may at times be as important to an officer, as to know the length of his own pace. When a rapid reconnaissance has to be made, it will be most useful to note *the time* taken to move from one point to another, so that a fair estimate can be made of *the distance* traversed. These are points, therefore, which deserve attention. Examples of them that are worth studying, will be found in *Chapter* I., *Comparative Scales. Nos.* 4 and 5.

5.—*Judging distance.*—The advantage, and importance, of being a good judge of distance cannot be over-rated. It is an art which should be practised on every opportunity, and under ever-varying conditions of ground, light, weather, &c. A man may be a very good judge of distance in a flat country, and yet make very bad guesses when he gets amongst hills. It is an excellent plan when sketching to write faintly on all bearings taken to distant objects their estimated distance. When these objects are subsequently intersected by cross-bearings, the sketcher will be able to see whether his estimate of their distance was anywhere near the mark or not.

Besides being a good judge of distance, anyone should be able to fairly estimate relative heights and slopes. One is apt to think slopes steeper than they really are. It is useful to remember that 15°, or a slope of 1 in 4, is the extreme limit of what are called manœuvring slopes. (*See Page 168*).

6.—*The rate at which sound travels* varies accordingly to the state of the atmosphere, the force and direction of the wind, &c.; but 380 *yards per second* may be taken as an average rate for purposes of calculation. Thus, the time noted between the flash and report of a gun enables one to estimate approximately its distance off. This might often prove useful during a reconnaissance.

In all the preceding remarks on measuring distances, nothing has been said about making any allowance for undulating ground. And yet, to get the true horizontal distance between any two points (which is what we want), it is evident a reduction must be made from the actual distances measured.

Thus, the distance measured up the slope AB, *Fig.* 47, and down to C on the other side, would obviously be a good

Fig 47.

deal more than the true horizontal distance A B′ C. In large surveys where minute accuracy is of the first importance, the necessary reduction is always made. It is ascertained by simply multiplying the measured distance by the natural cosine of the slope. This gives the true horizontal distance. Thus, in *Fig.* 47 if A B is measured to be 600 yards, and the slope is 10°, then the true horizontal distance A B′, will be 600 Cos. 10°. Cos. 10° is .98481; therefore the answer is 590.88 yards : showing a difference of 9 yards in 600, or about $1\frac{1}{2}$ yards in every 100. And even with so steep a slope as 15° (a slope which is very difficult for cavalry to move on, and all but impracticable for artillery), the difference is only about $3\frac{1}{3}$ yards in 100. Now in a scale of 6 inches to a mile, $1\frac{1}{2}$ yards, or even $3\frac{1}{3}$ yards, is almost an inappreciable distance ; therefore, for practical purposes the error is unimportant, and no allowance is made for it.

7.—RANGE FINDERS.—*The Mekometer* is the authorized Range Finder for all branches of the Service. A Handbook on the instrument, which can be obtained from any military publisher, fully explains its use.

Range finders may be very useful on service for making a sketch of country occupied by an enemy. Very good sketches were made in the South African War at the Tugela River with these instruments. A range finder might also be used in conjunction with any of the means for military sketching.

All combatant units are provided with it, and its practical use can be learned by any person of ordinary intelligence in an hour.

Another useful pattern of range finder is the *Telemeter*.

QUESTIONS FOR PRACTICE.

1.—An officer is sent with a small cavalry escort to reconnoitre the alignment and length of an enemy's encampment. On reaching an eminence whence the whole front of the camp is visible, he observes it to be in a straight line, and takes the bearings of the extreme right and left flanks, which are respectively 345° and 30°. Remaining himself in the same position, he then directs a part of the escort to ride rapidly along the front of the camp, in order if possible to draw the enemy's fire. This they succeed in doing as guns on the extreme flanks open on them. The officer notes the time elapsing between the flash and report of the guns on the right and left flanks to be respectively 10 seconds and 7 seconds. He calls in the detached portion of his escort, and returns to headquarters, where he furnishes a report, showing the bearing and length of front of the encampment, and its exact position with reference to the point of observation. Give the same information as that submitted by the officer, with a diagram to the scale of 1000 yards to an inch.

2.—You find after several trials that 107 of your paces go to 100 yards. Construct a scale of paces for your own use, scale 6 inches to a mile.

VI.—THE FIELD BOOK AND TRAVERSING.

A *Field Book* (*see Definitions*) is simply a Pocket-book, with a column ruled lengthways up the centre of each page. This is called "the chain column," and the spaces on each side of it are called "the offset columns." If we are going to make a traverse (*see Definitions*) we can get to work in two ways. Either we can take a sketching case and protractor, &c., and plot our observations as we go along; or we may take only the Prismatic Compass and Field-book, and recording all our observations in the latter, plot them afterwards at our leisure on reaching home. This is the method chiefly employed by civil surveyors in England, but it is seldom had recourse to for military purposes. Yet it is obvious that there may be many occasions when it would be the only way in which required information could be obtained; as for instance, when secrecy is desirable; or when the weather is wet and stormy, and to sketch would be quite impossible; or when only a very limited time is available for outdoor work. Therefore it is necessary that every officer should know not only how to keep a Field-book, but also how to plot from one that has been kept by someone else.

How to Traverse with a Field-book.

(*a*) The entries in the Field-book are commenced at the bottom of the last page, and continued upwards towards the first page.

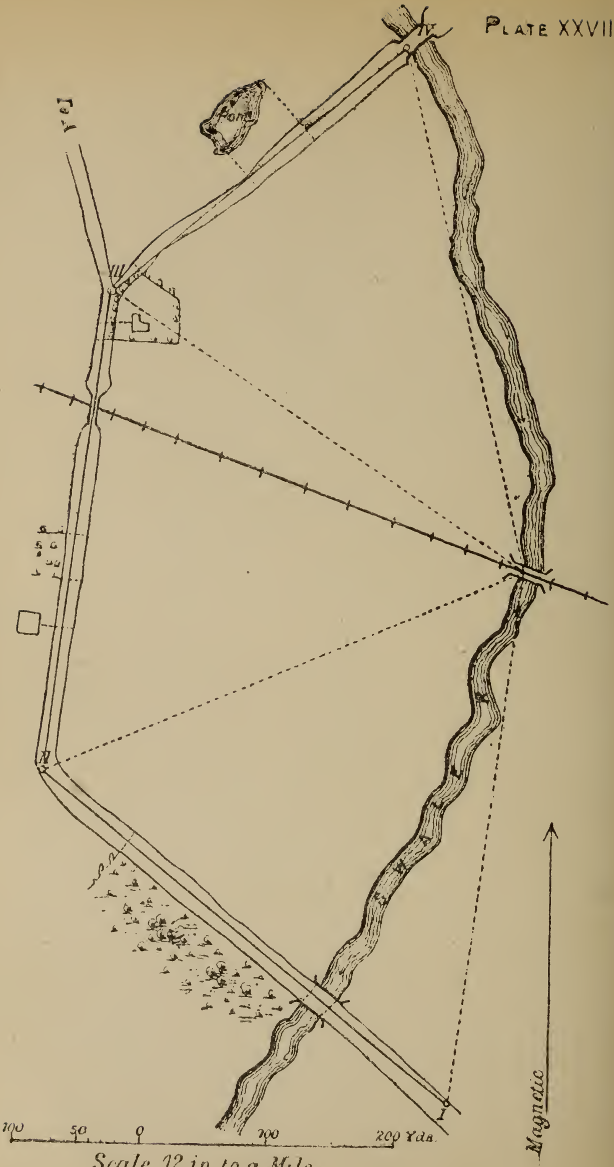
(*b*) A point is selected to start from, and marked in the chain column thus, ⊖ I., which means *Station No.* 1. Immediately above this is entered the forward bearing to the next station on the road, or line, about to be traversed.

(*c*) To the right and left of this entry, in the offset columns, are written down the distances measured at right angles to the traverse line, to the sides of the road, or to houses, or objects off it. These distances (in military sketching) may generally be estimated. As a rule, offsets need not be taken to objects more than 200 yards, or so, off the line. More distant objects, if to be noticed at all, may be fixed by bearings taken to them. It must be clearly shown from what spot these bearings are taken (*see example at end of this chapter*), and they are recorded in the offset columns, not in the chain column.

(*d*) Having made all the observations necessary at the starting point, pace forward, taking care to march strictly on the forward bearing. As you proceed, if you notice anything that should be recorded, such as an alteration in the width of the road, or houses, plantations, &c., alongside it, you stop and put it down, thus:—First enter in the chain column the total number of yards traversed up to that point, then enter in the offset columns whatever has to be noted. And observe, in these offset columns you not only write down distances, but also as you go along, you make a rough outline representing the sides of the road, houses, hedges, woods &c. Nothing is drawn to scale, but simply you make what may be called *pictorial memoranda* which will help you afterwards to remember clearly what you saw.

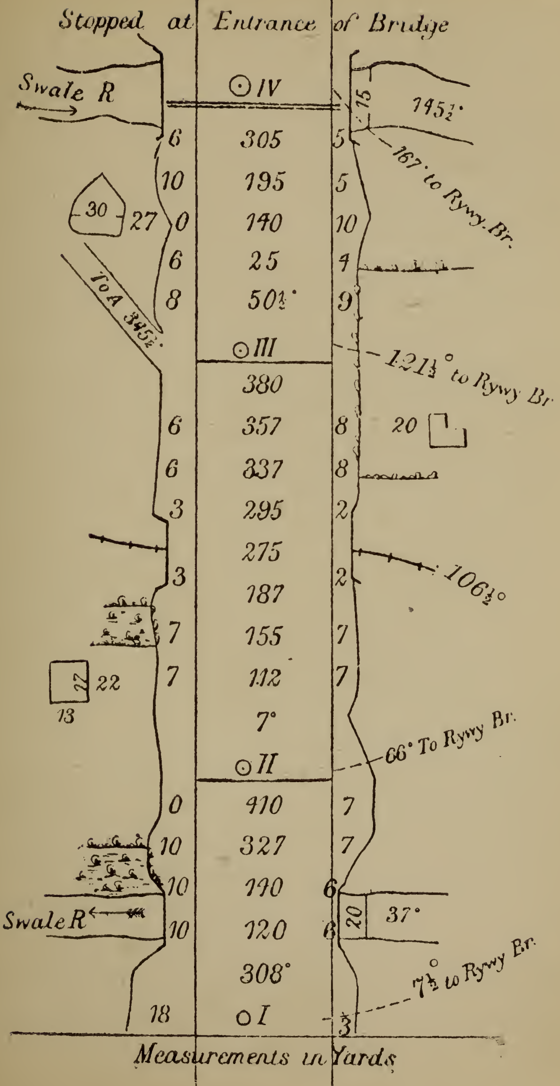
(*e*) Remember that the *only* entries made in the chain column are the forward bearings, and the distances measured along them.

(*f*) The chain column represents a line having no breadth; therefore, if a hedge, line of telegraph, &c., crosses



Scale 12 in to a Mile

PLATE XXVIII.



your forward direction obliquely, it must be shown arriving at, and leaving, points exactly opposite each other, on opposite sides of the chain column. Its bearing may be written on it if considered necessary.

(*g*) In this way continue to pace on your forward bearing, recording observations right and left as you proceed, until you reach a bend, and a fresh forward bearing becomes necessary. You now stop, write down in the chain column the total distance traversed from ⊙ I, draw a line right across the chain column, and immediately above it enter ⊙ II, and the new forward bearing. This done, you go on exactly as before until your task is completed. The following cautions must, however, be borne in mind :—

1.—Be careful never to crowd your entries. It is a good plan to rule lines for them about one-third of an inch apart. Your work should be so clear and intelligible that another person can plot it without difficulty.

2.—All intermediate measurements between stations are inclusive. Fresh counting is only commenced at a new station.

3.—In the same way offset measurements are inclusive. Thus, if from the traverse line to the side of the road is 15 yards, and a house stands 25 yards beyond that, then the entries would be —— 15 ; then a line representing the side of the road, then 40, then a rough outline of the house, which is thus understood to be 40 yards from the traverse line.

4.—All station lines (*see definitions*) should be as long as possible. The fewer and the longer that they are, the less is the chance of error in the traverse, and time and trouble are saved.

5.—Whenever it is practicable, a traverse should always begin and close on stations which have been fixed by triangulation. If this is not possible, then, in order to have some means of checking your work, seek for some conspicuous point off your line, and intersect it as opportunity affords. In the example given at the end of this Chapter (*Plate* XXVII.), the railway bridge has been thus utilised, and the "work closed" on it satisfactorily.

6.—Have regard to the scale on which your work is to be plotted, and do not waste time in offsets, or measurements, too small to be represented.

Plotting the Traverse.—The first step is to lay down the forward bearings in succession from start to finish, and the total distance measured along them from station to station. By doing this, it is seen at once whether the traverse closes correctly. As soon then as this is done, and you are satisfied of the general correctness of the work, you return to ⊙ I, and commence to plot the offsets. Each forward distance is taken in succession, and its corresponding offsets laid off perpendicularly to the right and left. The drawing paper should always be turned so that the direction of the forward bearing along which you are plotting the offsets, may correspond with that of the chain column in the Field-book. Without this precaution you are apt to plot the offsets on the wrong side of the road.

It has already been explained what are the advantages of working with a Field-book. It only remains to state that the great disadvantage of using one is, that when you come home and plot your work, and find some mistake in it that you cannot explain, it is almost certain that you will have to revisit the ground to put it right. Such a mistake may easily be made through inadvertence, by one not accustomed to keeping a Field-book; and, as it entails serious inconvenience, and loss of time, it shows the importance of great care, and of making every entry quite clear and unmistakable.

For sketching in thick jungle or forests, or for long continuous sketches made while mounted, the Field-book is useful, especially if marching with troops, etc. In these cases the distances are best estimated by the time taken in getting from one station to another, and the rate of marching judged.

All that can be done is to sketch in the line of track.

A convenient form of note book is made by ruling four lines half-an-inch apart down the centre of the page. In the centre column are noted the *forward bearings*, on the left the *time*, and on the right the *rate of marching*. Should it be impossible to note the forward direction of the track, it is a good plan to take bearings of one's direction of march every few minutes. The time taken in noting bearings, etc., need not be booked, unless it is several minutes; it is enough to record the rate of march and the intervals can be included in it.

Traverses can be made from a boat or wagon in a similar manner. Excellent work has been done in Africa by these methods.

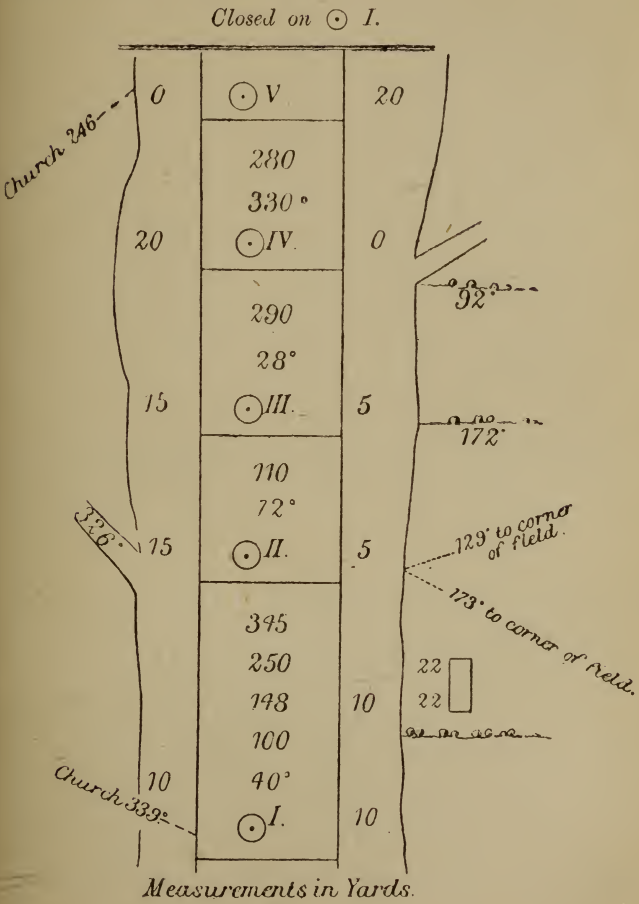
The only difference between traversing with a Field-book, and without one, is that in the former case you record your observations in a book, to be plotted afterwards at your leisure; whereas in the latter, your Sketching-case and Protractor are taken with you, and you plot each observation on the spot. Beyond this, the procedure is the same in both cases. If working with a Prismatic Compass, the paper must be, of course, prepared before starting with magnetic meridians. The manner of ruling these so as to keep the whole traverse on the paper has been fully explained in the chapter on the Prismatic Compass, &c. If working with a plane table, you would set it up at your starting point, then revolve the board so that its longest axis shall lie in the general direction of the road, or line, you are going to traverse; then clamp it, and placing the compass on one corner of it, move it about until the needle points to the north, then draw a pencil line along it (north end marked with an arrow head), so that at any subsequent station the table can be "set" by aid of the compass, and reference to this line. (*See remarks on traversing with the Plane Table, Chapter* V. *page* 104). We are now ready to start. We will suppose you are at ⊙ I, and have observed and plotted your first forward bearing. If there are other bearings to be taken from this point, take them and plot them at once, writing on them faintly what they are to: then sketch in by eye—the road, as far as you safely can, fences, houses, trees, &c., on either side; and, in short, do all that is to be done on the spot. Now commence pacing forward, keeping strictly to your line. If you pass a house, a bridge, &c., stop, and judging the offset, put it in at once in the proper place. Each time you stop, take the opportunity to work in all details; the sides of the roads, trees, printing, &c., up to that point. This is a much better plan, at all events for a beginner, then to make, so to speak, only a skeleton sketch, which will require an hour's work, or two, on it, at the end of the traverse, before it is presentable. Also, lose no opportunity as you proceed, of intersecting distant points. It is not only good practice in judging distance, but some of them are sure to be useful afterwards, affording you means of checking your work, or perhaps of closing it satisfactorily. The necessity of having regard to the scale of the sketch has already been alluded so. Two inches to a mile is an ordinary scale for a road traverse. This is a very small scale, and the sketcher will find that until he has had some practice, his tendency will be to take note of many things, and distances, which are really too small to be reproduced. This of course involves a loss of time. A fair rate of progress for a road sketch, made on foot, is about one mile an hour. This means that the sketch is neat and complete, embracing at least half-a-mile of country on each side of the road, and that a report is handed in with it giving all the information required, regarding the route traversed. An experienced reconnoitrer will of course often do more than this. Excellent work can be done with a bicycle fitted with a cyclometer. There is no counting paces, and all that has to be done is to note the distance registered before starting and when you halt, subtract one from the other, and you have the distance covered.

QUESTIONS FOR PRACTICE.

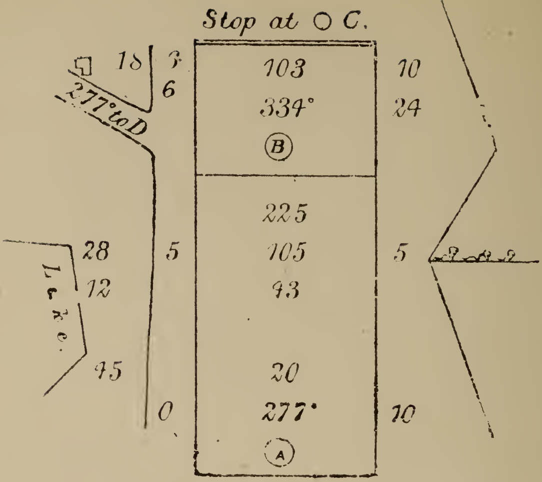
1.—What are the advantages and disadvantages of working with a Field-book? What entries are made in the chain column, and what in the offset columns?

2.—Reproduce a portion of an imaginary Field-book, showing two forward bearings taken along a hedged road about 50 feet wide. On the right is a large tree about 200 yards from the road, and on the left a church about 300 yards from the road. Plot the same. Scale $\frac{1}{5280}$.

3.—The following entries in a Field-book are to be neatly plotted. Scale 6 inches to a mile. Give the bearing and instance from ⊙ V. to ⊙ I. :—



4.—Plot the following extract from a Field-book, scale 24 inches to a mile :—



5.—Explain how you would survey a sinuous line, such as a stream, or an irregular fence, with a Prismatic Compass.

CHAPTER VI.

INTERSECTION OF STATIONS.

Whenever a tract of country has to be surveyed, an intersection of stations of some sort is absolutely necessary, and the first step towards carrying it out is the selection and measurement of a base line. In an extensive military *survey*, in which accuracy rather than rapidity is aimed at, the intersection is a process quite distinct from the sketching in of the details. It would be planned, and executed, by experts, who would use the best instruments obtainable for observation and measurement, and would take every precaution to fix the stations selected with great exactness. This being done, the features of the ground, and all minor details, such as roads, streams, villages, woods, &c., would be sketched in by degrees by regimental officers, who would base their work on the intersected stations, pricking them off on their sketch sheets as required, and thus a reliable map of the country would eventually be produced. But often a sketch has to be made without any intersections, or other fixed points being available as guides. In such a case the sketcher must arrange intersections for himself, and will begin, of course, by examining the ground, and selecting the best base, according to the rules hereinafter given. But there may not be time to do all this. Recourse must then be had *to* "*a running intersection;*" that is to say, there being no fixed points to go by, and no time to look carefully over the ground, select the best base, and lay out a regular intersection of stations; the intersection is started from the most convenient spot, and the sketching in of details is commenced at the same time, the triangles being extended gradually, as opportunities are afforded in the progress of the work for the intersection of distant points. An example of this method of working is given at the end of this chapter. It is the method likely to be most generally useful to an officer on service; but the principles on which it is conducted are the same as those which govern the more scientific system; and these will now be briefly explained.

The first consideration, then, is the selection of a base. The accuracy of all the subsequent work depends upon the selection being a good one, and upon its accurate measurement. Now in making the selection the main points to keep in view, are—(*a*) the position, and (*b*) the length of the base.

As regards its position, it should be centrally situated, because stations remote from the base are less likely to be correctly fixed than those in its immediate neighbourhood which are fixed by observations from its ends. The subjoined diagram, *Fig.* 48, clearly shows this:—

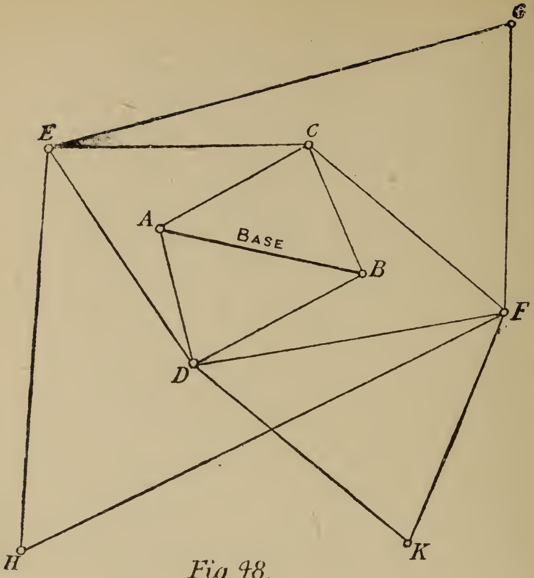


Fig. 48.

G is only correctly fixed if E and F are, and they, in their turn, depend upon C and D. Therefore, if a mistake has been made in any one of the observations necessary to fix C, D, E, or F, that mistake will affect G. Therefore, in order to minimise the chance of error from this cause—remoteness from the base—the base should whenever practicable, occupy a central position, its ends should be clearly marked, and from them some, at all events, of the principal points to be fixed should be distinctly visible. Of course those stations which are fixed by observations made directly from the ends of the base have the best chance of being accurately fixed. But it has already been explained that it is wrong to try to fix too many stations in this way. Bad intersections are sure to result, and they of all things are to be avoided. Anything under 60°, or over 120°, is considered bad: and, therefore, this general rule may be deduced for guidance as to whether a station may be safely fixed from the base or not. If the station is not much further from the base than the length of the base, and lies somewhere inside a perpendicular to the base at either end of it, then it *may* be reliably intersected ; otherwise not.

We see then why the base should be centrally situated. Another point with regard to its position is that it should be laid out on ground which is fairly level, and free from obstructions, which may interfere with its accurate measurement upon which so much depends. If the ground is very undulating (*See page* 121) or covered with brushwood, or intersected with banks, or ravines, &c., it is evident that it must be very difficult to measure over it correctly; therefore, it is an imperative condition that the line selected must lie over fairly good ground.

So much for *the position* of the base. The next point to be considered is *its length*. This must be proportionate to the area to be surveyed. However, a base that is somewhat too long is preferable to one that is too short. If a base is too short, either we get stations closer together than we require them (making the work unnecessarily tedious) ; or if we try to fix more distant stations at once, we are compelled to use intersections too acute to be reliable. For a sketch of 2 or 3 square miles of country a base should not be less than 800 yards long, and might with advantage be as much as 1200 or 1400 yards.

On looking over the points which have been enumerated as desirable in a good base, we notice that sometimes they must clash with one another. For instance, it may be impossible to secure a central position, and at the same time good ground for measurement. It is then for judgment and experience to decide what is best to be done under the circumstances, and how far one condition must be made to yield to another. We will briefly recapitulate all the conditions, and then see what expedients there are for overcoming some of the difficulties that may arise in connection with them.

Conditions desirable in a good Base-line :—

(*a*) It should occupy a central position. This, however, is not of very great importance.

(*b*) Its ends should be clearly marked, and, if possible, a good view over the country should be obtainable, and some at all events of the chief points to be fixed should be distinctly visible.

(*c*) It should be laid out on ground fairly level, and free from obstructions which would interfere with exact measurement.

(*d*) Its length should be proportionate to the area to be sketched. It should be about a half to one mile long.

It need not be pointed out that often it may be impracticable to secure all these conditions. Then we must do the best we can under the circumstances. Thus, suppose (*a*) not possible, then it would be all the more necessary to secure (*b*) in such perfection, that the non-fulfilment of (*a*) would be comparatively unimportant. Frequently (*c*) or (*d*) are not attainable, but this difficulty may be thus managed. Suppose that a base is required from C to D, *Fig.* 49, but

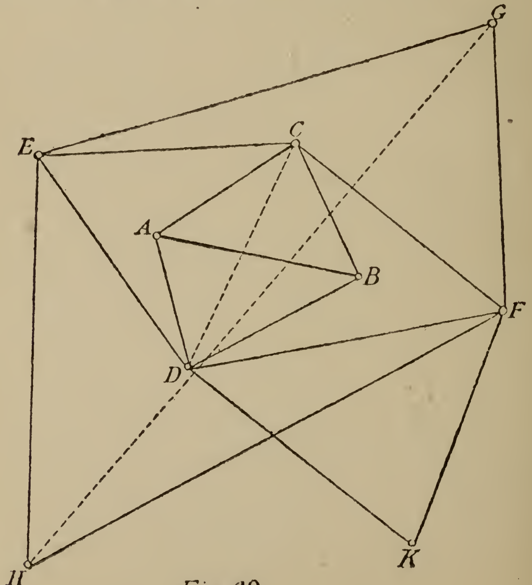


Fig 49.

direct measurement between these points, owing to broken ground, &c., is not practicable. Two other points, A and B, are then sought for, and found, between which direct measurement is easy, and by observations from which C and D can be accurately determined, the intersections obtained being good ones. In this way C D has practically become our base, and using it as such, we can now proceed to fix more distant points, and on the same principle continue gradually to increase the size of our triangles till we have got them to any size that we want. This method of extending triangles is considered a better one than that of building one triangle upon another.

We may now notice some points connected with the triangles themselves, viz., their form and number; and finally some means of checking the work when it is finished.

First, with regard to their form, it may be remarked at starting, that if a regular triangulation is to be carried out with instruments of precision like the Theodolite, or the Sextant, each triangle must be complete in itself (as in the diagram of a triangulation shown in *Plate* XIX.), because all its angles must be known in order that its sides may be calculated. But when what may be called a secondary triangulation or intersection of stations is observed with a Prismatic Compass, or Plane Table, there is no such necessity; and the chief point that we have to be careful about, is that on which stress has already been laid so often, viz., good intersections to fix every station. From the subjoined diagrams (*See Fig.* 50), it is easy to see that if there is the slightest inaccuracy in the direction of lines meeting at a very acute angle (A), or a very obtuse angle (B), the position of the point of intersection is very seriously thrown out; and indeed, even if there is no error of direction, it is not at all easy to mark the exact spot where such lines do intersect. Whereas, if the intersection is at right angles, as at C, the same amount of error in observation, or plotting, will not make such a great difference in the position of the object. Theoretically, therefore, an intersection of 90° is the best. But in practice, an intersection of 90° could but rarely be secured, and it is moreover apt to result in a loss of base for subsequent observations An intersection of about 60° is therefore

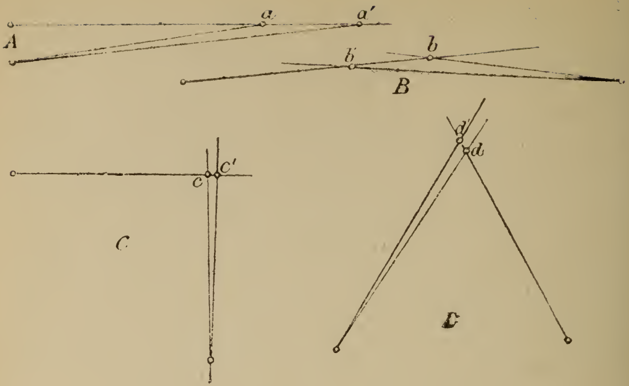


Fig. 50

preferred to it, because it is more easily arranged for, and while it fixes a point with sufficient accuracy (*See D. Fig.* 50), it helps in the formation of equilateral triangles, and thus the bases for subsequent observations are not shortened.

The number of triangles, that is, the number of stations, need not be great. Their distribution over the sketch, and their conspicuousness, and consequent usefulness, are of more importance than their number. It is useful to remember that *on paper, stations should be fully 1 to 3 inches apart according to the scale of the map.* In an open country they may be more than that with advantage. Therefore their number will depend to a great extent upon the scale of the sketch. If the scale was 6 inches to a mile, we should look out for stations about half a mile apart (3 inches on paper), and so on.

Finally, we come to the methods of checking the accuracy of an intersection of stations. This may be done in two ways. One is called "*the Angular Test*" (or *taking a check angle*, or *check slot*, or *check bearing*). It is particularly applicable to Prismatic Compass, or Plane Table work, is very simple, and takes no time, therefore it should frequently be applied. It consists in taking the bearing of a station already fixed, from some other station. These two stations (for the test to be a valuable one) should be as far apart as possible, and on opposite sides of the base. The observed bearing is then plotted, and if the line representing it passes exactly through the station observed, it is proof that all the work between those two points is accurate. If it passes a little to one side of it, there must be a small error somewhere.

For example, referring to *Fig.* 49, if standing at H, we take the bearing of G, and on plotting it find that it passes exactly through G, it satisfies us that the work on both sides of the base is correct.

The other method is known as "*the Linear Test,*" or *Measuring a Base of Verification.* It is the test usually applied to large surveys. It consists in carefully measuring a side of some triangle, the further from the base the better, and comparing this measurement with the distance representing it on paper. If the two agree, the work on that side of the base is accurate. If they don't, there is a mistake somewhere.

Our remarks on the intersection of stations may now be summed up thus:—

(*a.*) Many stations are not wanted. *On paper* they should be one to three inches apart.

(*b.*) We should be guided in selecting them by their conspicuousness, and consequent usefulness; and to a great extent by the consideration whether the lines fixing them will form equilateral or well-conditioned triangles.

(*c.*) In any case bad intersections must be avoided.

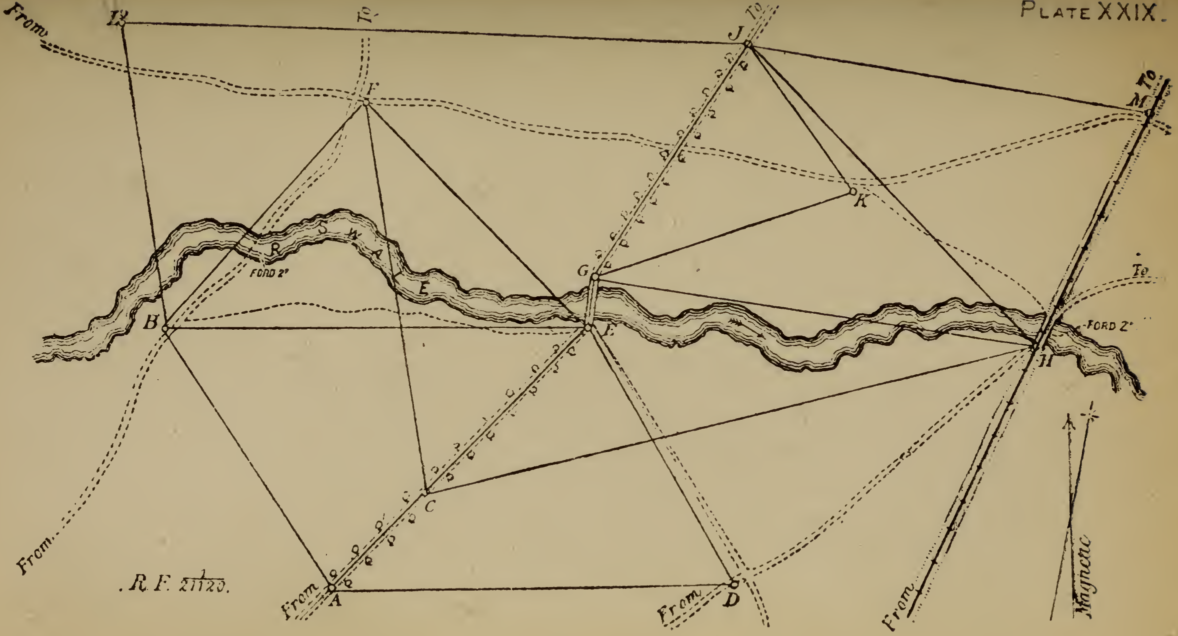
(*d.*) We should check our work occasionally by applying the Angular or Linear Test to it.

A few words about "*a running intersection,*" and we may quit this subject.

It has already been explained that a running intersection is resorted to when there is not time to examine the ground, and pick out a good base, and good stations, and fix them methodically and with deliberation. Still, if the work is intelligently executed, there is no reason why the resulting sketch should not be a very fairly accurate one. The great thing in this kind of work is to keep a sharp look out for conspicuous points away ahead, and the right and left. Lose no opportunity of intersecting such points. They are sure to be useful to you afterwards. Draw lines to them faintly in the first instance, so that they can easily be rubbed out if not wanted.

Let us suppose you start from A, *Plate* XXIX., to make a sketch of about two square miles of country in front. You commence by taking the bearing of the road. Then you see a village, B, on your left front, and another, D, away on your right. You take the bearings of both, and plot them. Next you sketch in by eye all the ground in your vicinity, and then commence to pace up the road. After going a short distance you come to a mile stone, C, and stop and put it in; and take the opportunity to look and see if there is any distant object that it would be advisable to take a bearing to. Yes, there is a village at F, and the railway bridge visible at H. You plot both these, then continue your pacing. At E you reach the bank of a river. Here you stop, mark E on your paper, and, observing that the direction of the road changes, take a fresh forward bearing to G. Next you take the bearings of B and D, which are now fixed. You also take the bearing of F; but its intersection with that previously taken from C is too acute, and therefore unreliable; and it will have to be checked presently by a further observation. Now you set to work to sketch in all details up to the point you have reached—the road, the bridge, the stream, &c., &c. While doing this, always hold your sketch as nearly as you can in its correct position with regard to surrounding objects. Having done all you can at E, you would probably gallop (if you had a horse) to B, which is already fixed, and there sketch the general shape of the village, and make any notes about it that you want; then sketch in more of the river, &c., and take a bearing to a conspicuous tree, L, in the distance, on the chance of its coming in useful presently. You also get a check bearing to F, which is now satisfactorily fixed. You now return to E, and pace across the bridge to G, take a fresh forward

PLATE XXIX.


From
L
To
F
J
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To
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E
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bearing, and plot it. Bearings are also taken from this point to a village on the right, K, and to the railway bridge, H; but this is not to be relied on to fix it, giving as it does much too acute an intersection with the bearing CH. The next step would be to gallop to F, and do all the sketching in its vicinity that is to be done. All cross roads should be noted, and put in by eye, their bends being generally unimportant. Now, as there are milestones along the road, you can gallop straight to the next one, J, and halting at it, put it in, and thus at once fix your position, by simply measuring up one mile from the last milestone, according to whatever scale you are working on. You now take bearings to L, K, and H, and fix those points and then work up your sketch in all details up to the point you have reached. At M you notice a level crossing; you take its bearing, and ride out to it. You can now fix it by taking the bearing of H, and setting off from it the opposite of the bearing observed. The line of railway is thus got in without any trouble whatever. You ride along it for some distance, notice the height of its embankments, &c., then pay a flying visit to K. Here you learn there is a ford under the railway bridge. You gallop back to verify, cross the river by it, and home *viá* D.

The above is a rough indication of how such a sketch might be executed rapidly, but with considerable accuracy. It will be observed there was hardly any pacing in it, and consequently a minimum of fatigue to the sketcher. If the work had to be carried forward, L and M, both conspicuous points, would be sure to prove useful.

QUESTIONS FOR PRACTICE.

1.—What are the conditions desirable in a good base line, and why?

2.—Explain, with the aid of diagrams, the objections to the use of bad intersections in fixing a station.

3.—Show, by means of a diagram including 7 or 8 stations, your idea of a good intersection of stations; and using the same stations, show what you would call a bad one, and explain the mistakes made.

4.—Draw an intersection of stations suitable for a military sketch of 10 square miles, to be laid down on a scale of 4 inches to a mile. Why, in this question, is the extent of ground embraced mentioned? and why is the scale on which the work is to be laid down a matter of importance?

5.—Explain how the accuracy of the intersection of stations in the foregoing question could be tested.

CHAPTER VII.

EYE-SKETCHING.

An eye-sketch is a sketch made without any instruments whatever. A sheet of paper fastened on a board, a pencil, and a flat ruler, are all the implements allowed, and with these the work has to be done. A scale of some kind, is, of course, necessary, but it can be improvised in a few minutes by making equal divisions on the edge of a card, or on a slip of paper, and letting each of them stand for 100 yards. Now the principles of eye-sketching are exactly the same as those which guide us when sketching with instruments; only being now without any artificial aids, they must the more carefully be observed. For instance, to "set" the sketch at any station, we are entirely dependent upon the back angle; so we must always work by the longest lines that can be arranged, and check at every good opportunity. This is particularly necessary when it is a traverse that we are engaged upon. Anyone who has worked a Plane Table will make an eye-sketch without the least difficulty, and with ordinary precautions, will turn out very accurate work. It is simply Plane-Tabling without a compass, and without the tripod stand for the board, which must therefore be laid upon the ground on each occasion that the sketch has to be "set" and bearings taken. To align the ruler on a distant object, get behind it, and stand back a pace or two; then using a plumb-line, or holding a pencil up vertically, see if the edge of the ruler appears to correspond with it; and if it does not, move the board about till it does. This is a much more accurate method than going down on the knees and trying to look along the edge of the ruler, and will save a lot of stooping and fatigue.

Resection may be practised in eye-sketching by any of the methods explained for the Plane Table when worked independently of the compass.

An approximate true north point may be found by "setting" the sketch on level ground, and marking on it the direction of the shadow of a plumb-line held alongside of it at mid-day.

A rough approximation to the direction of the true meridian for finding one's way by the aid of a map, is to hold a watch with its face level, and with the hour hand directed towards the sun, then an imaginary line drawn from the centre of the dial bisecting the lesser of the two spaces or angles between the hour hand and the figure XII. will be the direction of the meridian, or south, in the northern hemisphere, within about 20 deg. This simple expedient is useful on horseback, and it enables one to hold the map with its sides nearly north and south without dismounting.

The explanation of this is that the sun at noon being always due south, if the hour hand is pointed towards the sun at that time it, of course, points towards the south. Now the sun (apparently) makes a complete revolution round the earth every twenty-four hours. The hour hand of a "24-o'clock" watch also makes one complete revolution in the twenty-four hours; thus it is obvious that it keeps pace with the angular movement of the sun in the heavens, so that whatever angular distance the sun has moved from the south the hour hand has moved the same from the noon-mark (12 o'clock) and therefore 12 o'clock will give the direction of the south when the hour hand is pointed towards the sun.

In an *ordinary* watch, as the hour hand makes *two* complete revolutions while the sun makes only one, its angular motion is *twice* as rapid as that of the sun, hence the distance it has travelled from the noon-mark (XII.) must be *halved* in order to find the direction of the south when the hour hand is pointed towards the sun.

CHAPTER VIII.

CONTOURS, HORIZONTAL EQUIVALENTS, VERTICAL INTERVALS AND SLOPES.

N.B.—In connection with this, and the four following Chapters, Part 2, of the "Definitions," Chapter III., should be attentively read.

Up to this point no mention has been made of the manner of delineating hills. We now commence this subject, and as we proceed, it will be seen that it is not only a very important, but a very interesting one; and at the same time simple and easy to understand if properly approached.

On a military sketch, hills are represented by contours; so the first questions which suggest themselves are: What are contours? What purposes do they serve? On what system are they drawn? Contours are imaginary lines running round a hill at the same level all the way round, and each contour represents a fixed rise, or fall, of so many feet. Thus one purpose served by contours is apparent at once. They enable us to say what is the height of any given spot on a map, either its absolute height with reference to some particular datum, or its comparative height with reference to some other spot. Besides this they show us the shape of a hill side; that is, whether it is convex, or concave, in section. And a third, and most important use of them is, that they indicate whether the slopes are steep, or gentle, and what is the exact degree of slope. All this information conveyed by contours is obviously of the first importance. If a slope is concave in section it can be seen throughout its length from top to bottom: whereas if it is convex, the bottom of the slope could not be seen from the top, and troops could assemble there unseen, and probably safe from fire too. Again, it depends upon the degree of slope whether it is practicable for manœuvring purposes, or not. Therefore, as all this information is to be derived from an inspection of the contours, it is clear what their value is. Wherever we see contours on a plan close together, there we know the hillside must be steep; and where they are far apart, there the slopes must be gentle. It is easy to understand this, if you can suppose yourself required to walk straight from the foot of a hill to the top, and to plant a picket in the ground at every vertical rise of 20 feet, say: each picket representing the position of a contour. If the slope you ascend is very gentle you will have to walk a long way before you have risen 20 feet, and have reached a contour. But if the ascent is steep, a very short climb will take you up the required height: and in that part of the hill-side, if you could inspect it from above, you would see that the horizontal distances between the pickets were very small; while on the gentle slopes they would be considerable. In short, where contours are close together the slopes are steep, and where they are far apart, the slopes are easy. But for military purposes, it is not sufficient to decide that a slope is steep or easy. We must be able to say, or ascertain, *what is the approximately correct degree of slope at any given spot.* Contours enable us to do this.

Omit

Formerly, when military sketches were made on scales about 6 inches to a mile, a "normal scale of slopes" was adopted, which had as a basis a 20 feet vertical interval for sketches of 6 inches to a mile, and for all other sketches the vertical interval varied in inverse proportion to the scale of the map. The principle was sound, but the 20 feet vertical interval at 6 inches to a mile was not a satisfactory standard.

Omit Obsolete Normal system

The rule to be followed in future is as follows :—

For scales of 2 inches to 1 mile and under,

$$\text{VI} = \frac{50}{\text{No. of inches to a mile of scale}}$$

From which we get the vertical intervals for scales of 2 inches, 1 inch, and $\frac{1}{2}$ inch to 1 mile, viz., 25, 50, 100 respectively.

For scales over 2 inches to 1 mile one may use a V. I. most suitable to the sketch being made.

It should be noted that if making a sketch on a scale of 3 inches to 1 mile, the vertical interval would be 16$\frac{2}{3}$ feet, an inconvenient number to work with. Use, therefore, 20 feet or 25 feet. The 1 inch ordnance maps have the 100, 200, &c., contours marked on them which, would be useful in making enlargements, &c. By using a 20 feet or 25 feet vertical interval every 5th or 4th contour would be given you on the map, and be a guide for interpolating the others.

The working of the "old normal system," though out of date, has not been cut out of this edition. It was very sound, and it is thought students interested in the study might like to understand how it was arrived at. *It was a system by which it was insured that no matter what was the scale of the map, the distance between the contours in plan should always be the same for the same slopes.* This means, for example, that if contours a quarter of an inch apart on paper represented a slope of 5° on one map, they represented that slope on every map, no matter what the scale was. The advantage of such simplicity was obvious and could not be over-rated. If they represented 5° on one map, and something totally different on another map, there would be endless mistakes and confusion; but on the normal system, where they always indicated the same slope irrespective of the scale, the eye very quickly got educated, and a slope was recognised as soon as the map was seen. Now how was this uniformity secured? In this way. It had been decided, as the result of long experience, that *at a scale of* 6 *inches to a mile the* [illegible] Normal [illegible]

vertical interval between the contours should be 20 feet. This was the basis of the system: and *for other scales, the vertical interval was varied in inverse proportion to the scale.* Thus, for a scale of 12 inches to a mile, the vertical intervals would be 10 feet; for a scale of 3 inches to a mile, they would be 40 feet; and so on. In other words, the larger the scale, the smaller the V. I. The smaller the scale the larger the V. I. The reason why 20 feet vertical intervals was fixed on with a 6 inch scale was this. The object was to delineate ground faithfully, but not to go into too great detail, to do which would be not only of no tactical importance, but also would involve great labour and expenditure of time. And experience showed that if at a scale of 6 inches to a mile, a contour was traced at every 20 feet V. I, the form and slopes of a hill were depicted with sufficient accuracy, while the labour was not excessive: Nor, even on steep slopes, were the contours brought so close together as to interfere with, and perhaps obscure, other details which it may have been necessary to show on the map. The foregoing remarks clearly explain what was meant by "*the old normal system,*" and on what basis that system was founded, and what its advantages were.

The following additional notes in further elucidation of the subject, will be found of interest.

It has been stated that to carry out the above, the vertical intervals varied in inverse proportion to the scale of the map; the object being to insure that for the same slopes the horizontal equivalents (*i.e.*, the distance apart of the contours in plan) should always be the same, irrespective of the scale of the map. The subjoined illustration shows the necessity of this. A B, *Fig.* 51, is a slope of 5°; B is a point 20 feet higher than A; and 76.4 yards distant from it. Let us suppose that this is a bit of a sketch on a scale of 6 inches to a mile.

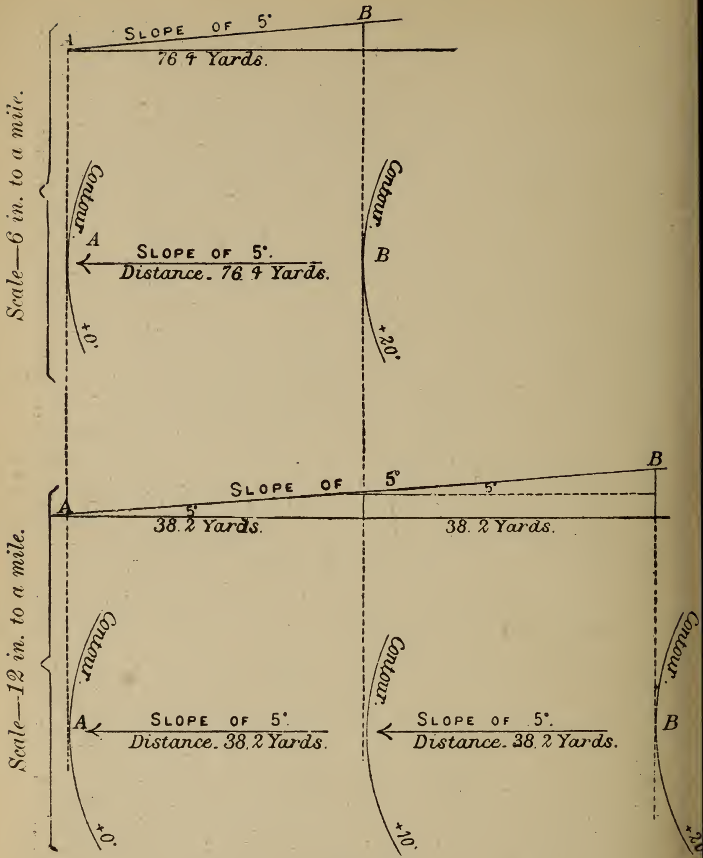


Fig. 51

Now, suppose the same ground has to be sketched on a scale of 12 inches to a mile. Then the distance A.B., 76.4 yards, will be in the drawing twice what it was before, as the scale is twice the size of the first one. But the slope is still 5°, and the height of B above A is still 20 feet. These are facts we cannot alter. But it is evident that if we now use only the two contours used in the first instance, when the scale was 6 inches to a mile, they will be so far apart as to be utterly misleading, for they would make the slope appear twice as gentle as it really is; so we put in a contour at every 10 feet (*see Fig.* 51), instead of at every 20 feet, and thus keep them *the same distance apart in both sketches.* The effect of this is that no one can be misled as to the steepness of the slope between A and B. It will be observed that the vertical interval is in inverse proportion to the scale. The scale is twice as large as 6 inches to a mile; the vertical interval is half of 20 feet.

It may be noted here, that this system of altering the vertical intervals in inverse proportion to the scale of the map did not give satisfactory results in cases where the scale was a very large, or a very small one. For example, if the scale was 24 inches to a mile, the vertical intervals would be only 5 feet. That is, if sketching on that scale, a contour would have to be traced, and put in, at every 5 feet difference of level. This would give needless trouble, and take up valuable time to no purpose, for it could never be necessary from a tactical point of view, to show ground with such minute accuracy as would be represented by contours at 5 feet vertical intervals.

Again, if the scale was 2 inches to a mile, the vertical intervals would be 60 feet. In this case, an elevation, or hill, 40 or 50 feet high, might not be shown at all by the contours, and its omission might be a serious matter. Of course, it *would* be shown by the help of *form lines* (*see definition*), but these instances are given to show that the normal system was not applicable to very large, or very small scales. Therefore, if such scales were used, the sketcher must drop the normal system, and fix such vertical intervals as he considered suitable, taking care to note them on the face of his sketch; and, *in addition*, to give "*a scale of slopes*" in the margin; so that no one examining his work might be deceived as to their steepness.

It may be asked here: How is the horizontal equivalent for any given degree of slope ascertained? It may be ascertained in two ways: (*a*) by construction, or (*b*) by calculation. The former method has already been referred to, and explained with an illustration, under the heading of "Horizontal Equivalent" in *Chapter* III. *Definitions*. The reader is invited to study the example there given Another one, which will make this system quite clear, is subjoined:—

Example.—Find by construction the horizontal equivalents for slopes of 3°, 6°, 10°, and 15°. Scale, 6 inches to a mile. V.I., 20 feet.

Draw two parallel lines 20 feet apart:—

[Here it is evident (as previously explained) that in questions of this kind the scale must be exaggerated: for on a scale of 6 inches to a mile, it is not possible to measure a distance of 20 feet with any accuracy, so we will exaggerate 6 times, and then the construction becomes practicable].

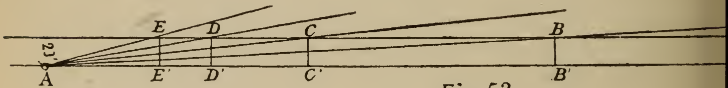


Fig. 52.

From any point, A, in the bottom line, *Fig.* 52, set off the angles given, *viz.*, 3°, 6°, 10° and 15°; and from the points B, C, D, and E, where they cut the top line, drop the perpendiculars BB′, CC′, DD′, EE′, to the bottom line, then the distance AB′ is the required horizontal equivalent of 3°, and being measured (allowing for the exaggeration), it will be found to be 127 yards. In the same way AC′, or $63\frac{1}{2}$ yards is the H.E. of 6°; AD′, or 38 yards, is the H.E. of 10°, and so on. The use of knowing this is, that if a contoured map is before you, scale 6 inches to a mile, and you have any doubt as to what the slope of a hillside on any part of it is, you can take the dividers and measure between the contours at that spot; and if you find the distance to be 127 yards, you would know the slope to be 3°; if you find it to be 38 yards you would know it was 10°; and so on.

We see, then, how to get the H.E.'s *by construction.* We now proceed to learn how we can ascertain them *by calculation.* The formula by which they can be rapidly calculated is this :—

$$\text{H.E.} = \frac{19.1 \times \text{V.I.}}{\text{D}}$$

H.E. being the horizontal equivalent *in yards.*

V.I., the vertical interval *in feet*, and D, the degree of slope.

Now, let us apply this formula to the last example, and note the result.

$$\text{For } 3^\circ, \text{ H.E.} = \frac{19.1 \times 20}{3} = 127.3 \text{ yards.}$$

$$\text{For } 6^\circ, \text{ H.E.} = \frac{19.1 \times 20}{6} = 63.6 \text{ ,,}$$

$$\text{For } 10^\circ, \text{ H.E.} = \frac{19.1 \times 20}{10} = 38.2 \text{ ,,}$$

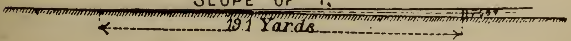
$$\text{For } 15^\circ, \text{ H.E.} = \frac{19.1 \times 20}{15} = 25.4 \text{ ,,}$$

and so on. Nothing can be simpler than this ; and as it is far quicker and more accurate than the "construction" method, it is the one that should always be adopted.

It may be pointed out here where the 19.1, used in the formula, comes from. It is the H.E. for 1° of slope, at 1 foot vertical interval ; that is to say, in a right-angled triangle, where the angle opposite to the perpendicular is 1°, and the perpendicular itself is 1 foot, the base (or H.E.) will be 19·1 yards. (*Fig 53*).

Fig. 53.

SLOPE OF 1°.



This triangle, therefore, may conveniently be called "*the triangle of reference*," because from the data it affords we can in any triangle calculate the base, whatever is the degree of slope, or length of perpendicular. Or, if we know the base and the perpendicular, we can calculate the slope; or with base and slope given, we can ascertain the perpendicular. In short, the three formulæ deducible from it are worth writing down and remembering. They are as follows:—

$$(1)\quad \text{H E} = \frac{19.1 \times \text{V. I.}}{\text{D.}}$$

$$(2)\quad \text{D} = \frac{19.1 \times \text{V. I.}}{\text{H. E.}}$$

$$(3)\quad \text{V. I.} = \frac{\text{H. E.} \times \text{D.}}{19.1}$$

Numerous examples of the use of these formulæ will be found further on. One other useful fact is derivable from this triangle of reference. It shows us what is the (approximate) gradient corresponding to any given degree of slope. In its own case, where the degree of slope is 1°, we see that the gradient is $\frac{1}{57.3}$, because the perpendicular is 1 foot, and the base is 57.3 feet (19.1 yards). Therefore, for a slope of 2°, it would be $\frac{2}{57.3}$: for 3°, $\frac{3}{57.3}$: and so on. But 57.3 is an awkward number to have for the denominator of a fraction, so it is usual to take 60 instead. The difference between them is inappreciable for practical purposes, and 60 is such a much more convenient number than 57.3, that it is always used. (*See remarks under heading of "gradients" in Chapter* III. *Definitions.*)

The V.I. should always be stated on a sketch and it is advisable to draw a "Scale of Slopes," or, as it is more commonly called, a "Scale of H.E." (for both mean the same thing).

What is "a Scale of Slopes," and how is it shown? "A Scale of Slopes" is a scale on which are marked off the distances in yards corresponding to each degree of slope, so that by reference to it, any slope on the map can at once have its proper degree of steepness assigned to it. A single example will make this quite clear. Suppose that a sketch is made on a scale of 6 inches to a mile, and vertical intervals of 25 feet are used. It is useful and advisable to show on the map the "Scale of Horizontal Equivalents." Before it can be drawn, the Horizontal Equivalents must be calculated. Let us calculate for the following degrees: 1°, 3°, 5°, 7°, 10°, 15°, and 20°.

$$\begin{array}{lllll} \text{For } 1^\circ & \text{the H. E.} & = \dfrac{19.1 \times 25}{1} & = 477\frac{1}{2} & \text{yards.} \\ ,, \quad 3^\circ & ,, & = \dfrac{19.1 \times 25}{3} & = 159 & ,, \\ ,, \quad 5^\circ & ,, & = \quad \&c. & = 95\frac{1}{2} & ,, \\ ,, \quad 7^\circ & ,, & = \quad \&c. & = 69\frac{1}{2} & ,, \\ ,, \quad 10^\circ & ,, & = \quad \&c. & = 47.7 & ,, \\ ,, \quad 15^\circ & ,, & = \quad \&c. & = 31.8 & ,, \\ ,, \quad 20^\circ & ,, & = \quad \&c. & = 23.8 & ,, \end{array}$$

The scale can now be drawn. Take a straight line, and using the scale of 6 inches to a mile, measure off on it distances of 477½ yards, 159 yards, 95½ yards, &c., and figure each space with its corresponding degree, thus :—

Fig. 54.

Scale of Slopes V.I. 25 feet R F $\frac{1}{10560}$

To use a scale like this when you see it drawn on a map, you have only to remember that wherever the contours are as far apart as the space on the scale marked 1°, there the slope is 1° : wherever they are as close together as the space marked 20°, there the slope is 20° ; and so on.

If a scale of slopes is not shown on a map one can be made. In any case, when the scale of the map, and the vertical intervals are ascertained, the slope at any point can be readily ascertained, either by means of the formula to find D previously given ; or, by making a fraction, having for its numerator the V.I., and for its denominator, the distance measured between the contours at the point in question. For instance, if the distance was 125 yards, and the V.I. 25 feet, then the slope would be $\frac{25}{125 \times 3} = \frac{1}{15} =$ 4° approximately

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EXAMPLES.

The following examples illustrate all that has been said in the foregoing chapter. They should be attentively studied, and then the "Questions for Practice" which follow them may be attempted with confidence.

1.—On the Normal System, what should be the vertical intervals in the following instances?

(*a*) Scale of the map being $1\frac{1}{2}$ inches to a mile.

(*b*) R.F. of the map being $\frac{1}{126720}$.

The basis of the calculations in answering the above questions is the formula—

$$\text{V.I.} = \frac{50}{\text{No. of inches to a mile (of the scale).}}$$

Hence, for (*a*) we have :—

$$\text{V.I.} = \frac{50}{1\frac{1}{2}} = \frac{50}{\frac{3}{2}} = 33\tfrac{1}{3} \text{ feet.} \quad \textit{Answer.}$$

Again, for (*b*) we have :—

$$\frac{1}{126720} \text{ is R.F. for } \tfrac{1}{2} \text{ inch to a mile,}$$

$$\therefore \text{V.I.} = \frac{50}{\frac{1}{2}} = 100 \text{ feet.} \quad \textit{Answer.}$$

2.—It is ascertained that the vertical intervals on a map are 25ft. The map being contoured on the Normal System, what must be its scale :—

$$25 = \frac{50}{\text{Scale of map in inches,}}$$

$$\therefore \text{ Scale of map} = \frac{50}{25} = 2 \text{ inches.} \quad \textit{Answer.}$$

3.—On a map, a point A is $4\frac{1}{2}$ contours higher than a point B. The scale of the map being 4 inches to a mile, how much is A above B?

Here, we must know what the vertical intervals are, when evidently $4\frac{1}{2}$ times the V.I. will give the answer.

We ascertain the V.I. as before, thus :—

$$\text{V.I.} = \frac{50}{4} = 12\tfrac{1}{2}.$$

$$12\tfrac{1}{2} \times 4\tfrac{1}{2} = 57\tfrac{1}{4}. \quad \textit{Answer.}$$

4.—A point A on a plan is exactly $1\frac{1}{2}$ inches from a point B, and the slope between them is 2.6°. Assuming that A is 90 feet higher than B, what must be the scale of the plan?

In this case we want to know the distance A B. This distance is represented by $1\frac{1}{2}$ inches, and thus we shall get the answer at once. To find the distance A B, we use the formula $\text{H. E.} = \frac{19.1 \times \text{V. I.}}{\text{D}}$ for it is the H. E. of 2.6° that we want to know.

We have, then, $\text{H. E.} = \frac{19.1 \times 90}{2.6} = 660$ yards (nearly)

Therefore, the scale of the plan is $1\frac{1}{2}$ inches to 660 yards : or,

$$\text{R. F.} = \frac{1\frac{1}{2} \text{ inches}}{660 \text{ yards}} = \frac{3}{2 \times 660 \times 36} = \frac{1}{15840} = 4\text{in. to}$$

a mile.—*Answer.*

5.—The scale of a French map is $\frac{1}{15840}$. The contours are marked at vertical intervals of 12 mètres, 1m. being equal to 39.37 inches. Construct a scale of Horizontal Equivalents for slopes of 1°, 3°, 5°, 7°, 10°, 15°, and 20°.

The V. I. here is expressed in mètres. We must have it *in feet.* Accordingly, we find :—

$$12 \text{ mètres} = \frac{12 \times 39.\ 37}{12} \textit{feet} = 39.37 \textit{ feet.}$$

We now proceed to calculate each required H. E. as follows :

$$\text{For } 1°, \text{ H. E.} = \frac{19.1 \times 39.37}{1} = 751.9 \text{ yards}$$

$$„ \ 3°, \ „ = \frac{19.1 \times 39.37}{3} = 251 \ „$$

„ 5°, „ = &c., &c. = 150 „
„ 7°, „ = &c., &c. = 107 „
„ 10°, „ = &c., &c. = 75 „
„ 15°, „ = &c., &c. = 50 „
„ 20°, „ = &c., &c. = 38 „

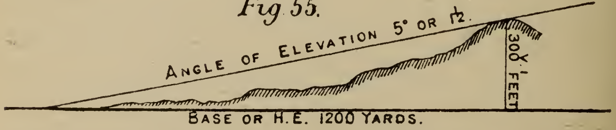
Now, having calculated the H. E.'s, we measure off the distances on a scale of 4in. to a mile ($\frac{1}{15840}$) and figure the Scale thus :—

Scale of H.E's V.I. 12 metres. R.F $\frac{1}{15840}$

6.—You observe with the Clinometer the angle of elevation to a hill, known to be 1,200 yards distant, to be 5°. What is its height ?

Questions of this class are extremely simple ; but it is a good plan always in answering them to draw a rough figure, as below (*Fig.* 55) and then one sees at a glance what is wanted.

Fig 55.



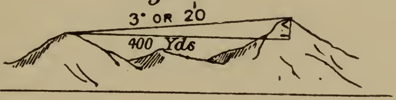
Here, as soon as the figure is drawn, we see that it is the V.I. that is wanted ; and the simplest way of getting it, is to work from the gradient corresponding to 5°, viz. $\frac{1}{12}$.

Then, the base being 1,200 yards, the V. I. must be 100 yards, or 300 feet.

Working from the formula V. I. $= \frac{\text{H. E.} \times \text{D,}}{19.1}$ we should get, not exactly, but practically, the same answer ; and it must be left to the judgment which method to adopt. As a rule, to work from the gradient is simplest and quickest.

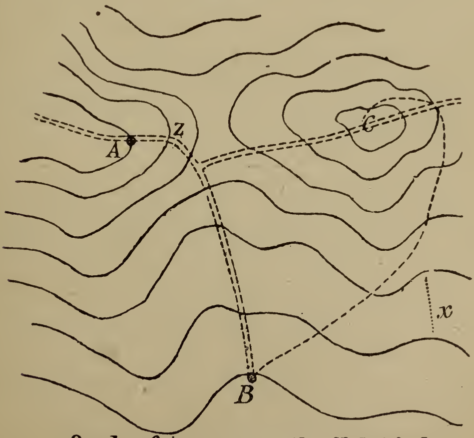
7.—Two hills are 400 yards apart. The angle of elevation from one to the other is 3°. What is the difference in their height ?

Fig. 56.



The V. I. in this case is clearly $\frac{1}{20}$th of 400 yards ; that is, 20 yards, or 60 feet.—*Answer.*

Fig. 57



Scale 6 in, to a mile. V.I 20.ft

8.—With reference to *Fig.* 57. What is the slope at the spot marked x?

The Vertical intervals are 20 feet, and the distance between the contours at x is measured, and found to be just 100 yards. Therefore, the slope is 20 feet in 300 feet, or 1 in 15, or 4°.

9.—What is the angle of depression from A to B? (*Fig.* 57)

The height of A above B is 120 feet, and the distance between them is 400 yards; therefore, the angle of depression can be seen from the gradient (which is 40 yards in 400 yards, or 1 in 10) to be 6°.

10.—What is the steepest gradient on the road AB? (*Fig.* 57)

The steepest bit is of course at z where the contours crossed by the road are closest together. The distance here is measured, and found to be 40 yards, and the V. I. being 20 feet, the gradient is $\frac{20}{40 \times 3} = \frac{1}{6} = 10°$. *Answer.*

11.—Trace a road from C to B, (*Fig.* 57) no gradient on the way to be steeper than 5°.

A slope of 5° is a gradient of 1 in 12. Therefore, with a V. I. of 20 feet, the base must be 240 feet, or 80 yards. This being determined the road is drawn by eye (*Vide* the dotted line) care being taken that its least length between any two contours is fully 80 yards.

QUESTIONS FOR PRACTICE.

1.—On the Normal System, what should be the Vertical Intervals in the following instances:—

(*a*) Scale of the map being $\frac{3}{4}$ inch to a mile.

(*b*) Scale of the map being $\frac{1}{14080}$, would this be a suitable V.I. What V.I. would you use and why?

2.—On examining a map drawn on the Normal System, you will find one hill-top marked 850 feet high, and another 700 feet high: one hill is seen to be 3 contours higher than the other. What is the scale of the map?

3.—A particular spot on a map represents a slope of 4°, and the distance between the contours at that spot is 48 yards. What is the scale of the map? The contours are drawn on the normal system.

4.—From the crest of a hill you walk 100 yards down a slope, and are then 30 feet below your starting-point: you then walk a further distance of 300 yards in the same direction over a slope of 1 in 12. Show, with the aid of a diagram, whether your starting-point is now visible or not, and give the angle of elevation to it.

5.—From the top of a Cliff 480 feet high, the angle of depression to a ship in the offing is 2°. Give the range.

6.—At a distance of 382 yards from it, the angle of elevation to the top of St. Paul's is observed to be 17.6°. What is its height?

7.—From the top of a hill 1,500 feet high, the angle of depression to another hill is 7°. This hill is 400 yards distant. What is its height?

8.—Standing on a hill 200 feet high, you observe the angle of depression to an underfeature, whose ascertained height above the same datum is 40 feet, to be 5°. How far off is it?

9.—Show how you would obtain the Horizontal Equivalents for slopes of 4°, 9°, and 15°, (*a*) by construction (*b*) by calculation. Scale, 12 inches to a mile. Vertical intervals, 40 feet.

10.—Construct a scale of Horizontal Equivalents for use on a map, 2 inches to 1 mile. It will be sufficient to show for slopes of 1°, 2°, 3°, 5°, 7°, 10°, 12°, 15°, and 20°.

11.—On a Russian plan, it is found that $2\frac{1}{2}$ inches = 1 Verst: and the contours are marked at vertical intervals of 17 Archines. 1 Verst = 3500 feet. 1 Archine = 28 ins.

(*a*) Construct a comparative scale of yards for use with the plan.

(*b*) Construct a scale of Horizontal Equivalents for it.

a. No V.I. given hence they may be anything

12.—If these lines)))) represent contours on a map of which the scale is $\frac{1}{63360}$, what are the slopes which they show?

13.—With the aid of a few contours, show a road rising from 0 to 60 feet, at a uniform gradient of 1 in 30. It then passes through a cutting 400 yards long, and 25 feet deep in the deepest part, and finally descends to 0 at an angle of 4°. The road is 20 yards wide, quite straight, and its bearing is due East.

Scale, 12 inches to a mile. Vertical intervals, 10 feet.

14.—What is the difference in level between A and C? The ground falls from A to an intermediate point B, distant 360 yards, at a slope of 7°: and thence rises to C, 180 yards off, at a gradient of 1 in 4.

15.—Draw 10 parallel lines representing contours at 20 ft. V. I. on a scale of 6 inches to 1 mile, the second $\frac{1}{8}$th of an inch below the first, the next one $\frac{1}{4}$th of an inch lower, and the remainder in succession at the following intervals:—$\frac{1}{3}$rd, $\frac{1}{2}$, $\frac{2}{3}$rds, $\frac{3}{4}$ths, 1 inch, $\frac{3}{4}$ths, and $\frac{1}{2}$ an inch apart. Number the fourth line from the bottom 0, and those above and below it, 20, 40, 60, &c. Draw a straight road, cutting the 10 lines at an angle of 40°. Show:

(*a*) That the steepest bit on one side of 0 is about 8°, and on the other about 2°.

(*b*) That the average gradient of the road above 0 is about 1 in 25: and below it, about 1 in $42\frac{1}{2}$.

(*c*) That to make the steeper of the two as easy as the other, a cutting about 50 feet deep would be required.

16.—Still using the same 10 lines, trace a road from the bottom line to the top on which no gradient is to exceed 5°, or to be less than 1 in 45.

17.—Draw concentric circles with the following radii: 1″, 1.33″, 1.75″, 2.75″, 3.25″ and 3.50″. Assume these circles to be contours of a conical hill at 25 feet V. I. Draw a path ascending from the lowest contour to the highest, at a slope of 5°. Scale, 100 yards to an inch.

CHAPTER IX.

SKETCHING HILLS.

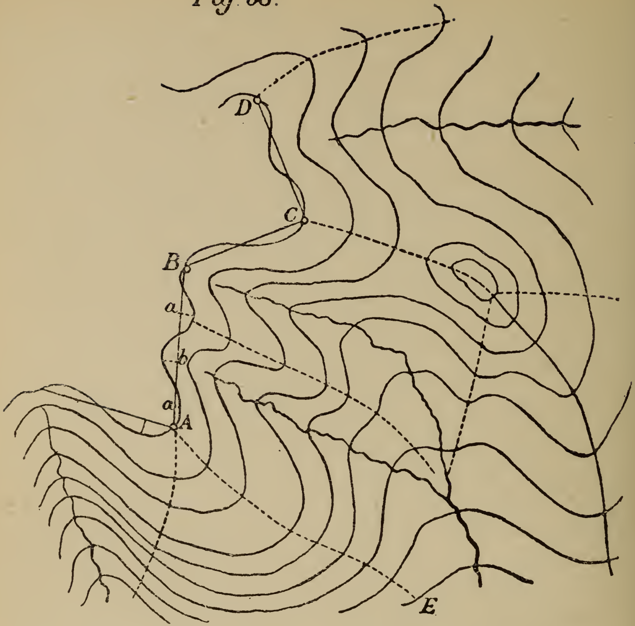
If the preceding Chapter has been attentively read, and the numerous illustrations in it carefully worked through, the student should now thoroughly understand the meaning and use of contours, and horizontal equivalents: also the principle on which vertical intervals are fixed according to the scale of a plan, for small scale maps, and how to answer any question connected with heights, distances, and slopes. We now pass on to the practical application of all this theory. It is, of course, one thing to understand a contoured plan when it is put before you, but quite another to be able to make one yourself. One may be thoroughly *au fait* in the theory of the subject, and yet not make much progress in the field: for ground varies so much in character, that to sketch it successfully, often requires special aptitude, and a good deal of judgment to decide how and where to commence work. Therefore, no hard-and-fast rules can be laid down for sketching hills. Only those methods and expedients can be indicated which have been found generally useful; and their application under different circumstances must be left to each individual's intelligence and judgment. Should any one find that he is not able to represent slopes correctly by the orthodox system of contours, let him not waste time in attempting to achieve the impossible, but endeavour rather by a few lines, or strokes, to show the general shape and direction of the principal features and watercourses; and ascertaining the inclination of the most important slopes with his clinometer, *write them down on the Sketch*, which thus, though it may have no pretence to finish, may still prove extremely useful, and at all events will mislead nobody. It need hardly, however, be pointed out that the more perfect a man is in the *regular* methods of working, the greater will be the facility with which he will be able to dispense with them, when perhaps, owing to want of time, bad weather, interference of the enemy, &c., they cannot be followed. Everyone, therefore, should try to master the simple instructions which follow: and opportunities of studying ground, and the conformation of hills, should never be lost.

When a portion of hilly country has to be sketched, and there is time to do it deliberately, it is usual to leave the delineation of the hills to the last. The reason for this is, that by first getting in correctly all the roads, villages, streams, &c., it becomes much easier afterwards to trace the general direction and extent of the hill features. They are, so to speak, checked for us, and kept within their proper limits, by the points and boundaries already fixed on the sketch. But for these, we should constantly be compelled to have recourse to the compass for their direction, and to pacing for their extent. Therefore, to save ourselves so much extra labour, we complete all the details of a sketch before commencing on the hills.

It is of special importance to have all the streams correctly put in. As our work proceeds we should take every opportunity of noting their direction, windings, and extent. This can be done by bearings, or resections at points along their course, and so forth. It is a matter of extreme importance, as by attention to it, much subsequent time and labour will be saved, and valuable aids and checks furnished to the subsequent work. So much is this the case, that if a sketch on which all the water-courses have been accurately traced, be put into the hands of an expert, he will, without having seen the ground at all, be able to fill in the main hill features with surprising correctness.

It is understood, then, that our sketch is complete in all details, and that particular attention has been paid to the streams and water-courses, which have all, so far as was practicable, been traced and put in, during the progress of the work. We are now ready to commence the actual delineation of the hills, and the first portion of them which claims attention is their crests. An experi surveyor will commence work indifferently at the top, or bottom, of a hill. But it is undoubtedly easier, and nine times out of ten, better, to commence at the top, and work down to the foot of a slope. By so doing you get a good idea of the general lie of the ground, and a better view over the slopes; and, therefore, a better appreciation of their nature, and practicability for various purposes. Moreover, pacing down hill is less fatiguing, and therefore more probably accurate, than pacing up-hill. So the first step is to go to the top of a hill, and sketch in its crest. This will give a good general idea of its shape, and of the way in which the main features radiate from it. The word *crest* here must not be taken to mean the absolute brow, or summit, of a hill, but *the highest* contour that will be shown. This will generally be several feet below the actual crest; but as a rule, within one vertical interval of the summit. For instance, if using 20 feet vertical intervals, the first, or initial contour, would probably be 15 feet or so below the summit. By keeping it thus pretty low down, the general shape of the hill is better defined, and the subsequent work probably easier, and more accurate. If there is time, the initial contour should be regularly traversed. A point, A, *Fig.* 58, is selected to start from; its position is found by resection (*Interpolation, see p.* 108), and marked on the sketch. Then by the aid of the Clinometer, another point, B, is found on the hill-side, on the same level as A, and its bearing is taken, and plotted. The more distant B is, the better, on the principle previously explained that in a traverse all station-lines should be as long as possible. We now pace towards B, sketching in the contour by eye as we go. It starts, of course, from A, and whenever we go over a slight rise, as at *a*, it will curve away from our line A B, and *outwards* from the hill: and if we dip into a hollow, as at *b*, it will bend in *towards* the hill. The extent of these bends can always be estimated. It would be waste of time to measure them. Arrived at B, we find a further point C, still on the same level, and traverse up to it as just explained: and in this way we continue, till we have traversed round the hill back to A, our starting-point, or have gone as far as is necessary for our immediate purpose.

Fig. 58.



We will suppose now that our initial contour is correctly drawn, and also, that while traversing it, the exact position of the heads of the chief salients and re-entrants has been carefully marked. We now commence the contouring, and this is done by working down the slopes in the following way:—We select a prominent feature A E to begin with, and plot the line that we mean to follow down it. Its direction may, if necessary, be taken with the compass, but in a finished sketch there will nearly always be some landmark enabling us to draw it by eye. Then, with the Clinometer, we observe the slope, and find it to be, say 5°. We now refer to our table of Horizontal Equivalents, and we find (the scale being 6in. to a mile, and vertical intervals 20 feet) that the H. E. for 5° is 76 yards. Consequently, we pace 76 yards down the slope, then stop, and measuring

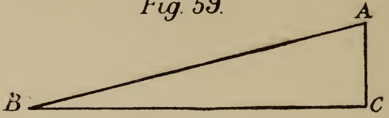
76 yards off our scale, put in a contour. Then we pace another 76 yards, and put in another contour: and so on. Suppose when we have put in three contours in this way, we find the slope has changed to 10°. We refer to our table of H. E.'s, and find that the H. E. for 10 is only 38 yards; consequently we stop now, and put in a contour at every 38 yards. And so we go on, altering the H. E. to suit the slope, until the bottom of the hill is reached. Other features can then be contoured in the same way, more than one line being followed down them if necessary (*See dotted lines Fig.* 58), and at last, a series of points are fixed all round the hill, the intervals between which, being joined by eye, we eventually get the whole hill regularly contoured.

The lines which we follow in pacing down a hill are called "section lines." Their number must depend upon the character of the ground, the size of the features, and in a large measure, upon the skill and aptitude for the work of the sketcher. The fewer that are used, consistent with accuracy, the better. As a rule, section lines will follow the watershed line of the feature on which they are taken. In this way, a better view, and therefore a better idea of the ground is gained. They will seldom run quite straight; but on the other hand, as previously explained, it will rarely be necessary to follow their bends with a compass. There is sure to be something on the sketch—a house, a wood, or cross-roads, &c.—to guide the eye in plotting them without instruments.

When pacing the Horizontal Equivalents along a section line, every time we stop to mark the position of a contour, the sketch should be held so as to correspond with the ground, and the contour traced to the right and left by eye as far as it can be safely judged. It is a good plan to turn round, and stand facing the hill to do this. If the water courses have been previously sketched in as recommended, they will now prove a great aid in defining the extent of the feature on which we are at work, and limiting the extreme inward bend of each contour.

The student will not have failed to remark that when pacing down a slope, A B, *Fig.* 59, it is really the hypothenuse,

Fig. 59.

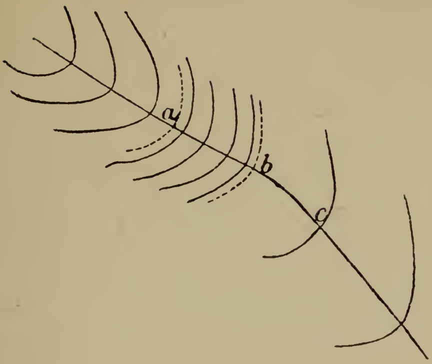


A B, which is being measured, and not the base (or Horizontal Equivalent) B C. But it has already been fully explained (*Page* 121) that even in moderately steep slopes, the difference between hypothenuse and base is unimportant, and too small to be worth allowing for, for practical purposes. Moreover, as a matter of fact, in pacing down hill, there is an involuntary elongation of pace, which to some extent compensates for the error.

Suppose we are pacing Horizontal Equivalents of 76 yards down a section line, the slope being 5°. In the middle of our pacing, that is, when we have come only 38 yards from the last contour, the slope suddenly changes to 10°. Now the H. E. for 10° is 38 yards; but as we have already come down half a vertical interval, we only go half this distance, 19 yards, and then put in another contour. The spot where the slope changed is marked by a dotted *Form line* at *a*, *Fig.* 60.

These form lines were useful when hachuring was in vogue, as a guide to the shading, but in rapid sketching they are minutiæ which need hardly be attended to. The point, however, involving their use, should be understood. Another case occurs a little lower down the slope at *b*, *Fig.* 60. The

Fig 60.

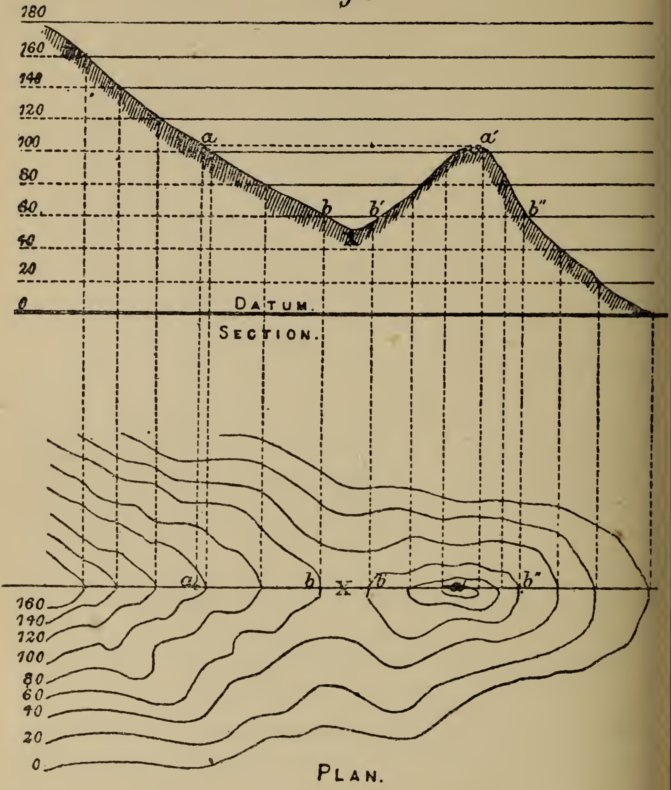


H. E. for 10°, viz, 38 yards, was being paced; but when only one quarter of the distance had been traversed, the slope changed to 2°. A form line was therefore put in at this point, and only three-quarters of the H. E. for 2°, viz. 143 yards, paced before the next contour, *c* was put in.

Underfeatures.—The following case is of common occurrence. As you are pacing down a slope, *Fig.* 61, you observe the ground rising in front of you. You are, in fact, coming to an underfeature. You would sketch it in as shown on *Fig.* 61, *p.* 166.

By means of the Clinometer, you ascertain, and note on your sketch, the point *a* when you are on a level with its summit. Then continue your work to the lowest point you can reach *X*. From this point you pace the distance to *a′*, the top of the underfeature (or, if preferable, find its position by resection) and then put in as many contours between *X* and *a′* as you have between *X* and *a*. From *a′* the contouring can be carried on to the foot of the hill in the usual way: and as the height of *a′* was noted when you were at *a*, there can be no difficulty about numbering the contours correctly.

Fig. 61.



Another method which is sometimes adopted is this :—

When the lowest contour, *b*, in front of the underfeature is reached, a point, *b′*, opposite to it, and on the same level, is found, and paced across to: and then (using the Clinometer if necessary) a third point *b″*, on the far side of the underfeature, still on the same level; and from this point the work is carried on to the foot of the hill. The underfeature is afterwards sketched in separately; its position being found by resection.

If a slope is uniform from top to bottom we need not pace it at all, except to ascertain its length, and that could probably be determined in some shorter way. For instance, suppose the slope to be uniformly 5° from top to bottom, we have simply to mark off on it distances of 76 yards till the bottom is reached, and it is properly contoured. But we can go a step further than this, if the distance is known from the summit where we stand to the foot of the slope; for then, whether the slope is uniform throughout or not, we can contour it with considerable accuracy without leaving our position. An example will best illustrate how this may be done. On a sketch of 6 inches to 1 mile, V. I. 20 feet, the general slope from top to bottom of a hillside is observed, and found to be, say 8°; and the distance, or base of the slope, is known to be, say 480 yards. We then see from our table of H. E's, that the H. E. for 8° is 48 yards; therefore, there must be 10 contours ($\frac{480}{48}$) in the distance.* Their own relative distances apart do not affect the question. They will be close together in parts where the descent is steep, and further apart where it is less so; but there will only be ten of them altogether. When contouring has to be done hurriedly, owing to bad weather, want of time, &c., valuable work may be produced by thus observing the angle, calculating the number of contours, and grouping them by eye. In mountainous districts, this is the only method practicable, for the hillsides are more or less precipitous, and pacing down them is impossible. In places of this kind, an Aneroid Barometer will be found very useful to assist in contouring, and would be worked on the principle just

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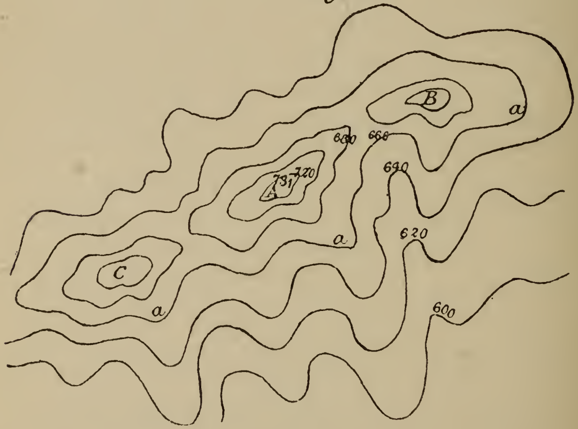
* The same result may be arrived at thus: Base and slope being known, height may be calculated from the formula given to find V.I. In this case, V.I. = $\frac{480 \times 8}{19{\cdot}1}$ = 200 feet; and as the contours are at 20 feet vertical intervals, there must be $\frac{200}{20}$ or ten of them altogether.

indicated. That is to say, we should use it to show us the difference in level between the top and bottom of a hill; and then noting how many contours will properly represent that hill-side, all we should have to do would be to group them by eye.

It must be remembered that a hill is rarely an isolated feature. It is almost invariably part of a range, or system; and often great judgment is required in laying out the work, *i.e.*, in deciding how to begin it. It is here that experience and aptitude tell, for as has been seen now, the mere process of contouring a slope by the system of pacing the Horizontal Equivalents, &c., is simple enough. But the selection of the initial contour in a difficult country is not such a simple matter, as much depends upon it. If the ground includes several adjacent hills, or heights, forming part of one range, it will generally be right to fix on an initial contour, such as *a*, *Fig.* 62, which will embrace all of them.

Fig 62.



The subsequent work will then be easier, and much more probably correct than if it had been commenced at the summit of B, A, or C.

Another important matter is the judicious selection of what are called "*reference points.*" We should look out for them when engaged in traversing the initial contour. They are conspicuous points, easily recognisable again ; such as houses, gates, remarkable trees, &c., situated on adjacent hills, and on the same level as the sketcher. When found, they are carefully noted for future use in the margin of the sketch. The use of them, scattered over the ground, is, that they enable you at any time to place yourself on a contour whose height is known. This gives you a starting point whenever you want it, from which you can work with confidence, knowing your contours will join correctly. When the hills are high and the features difficult, it is recommended to get "reference points" at levels of every 100 feet or so, care being taken to describe them accurately, with their correct height, in the margin of the sketch. They will be found most valuable aids and checks to the contouring.

The sketcher may be puzzled sometimes how to number his contours. There is no rule about it. If the true height above the sea of any point in the sketch can be ascertained, of course, the contours should be numbered with reference to it, and the level of the sea would be the datum of the sketch. Thus, in *Fig.* 62, if A is known to be 731 feet high, the top contour might be marked 720, the next lowest 700, and so on, according to the V. I. used.

But in most cases it is the simplest plan, while the sketch is *in* progress, to number the contours 1, 2, 3, 4, &c., beginning with the highest, as that is generally traced first. This can be done in pencil ; then when the sketch is finished, the numbering can be re-adjusted according to the vertical intervals that have been used, either with reference to the lowest point in the sketch, or with reference to some assumed datum. It is not a matter of much importance, for after all, for military purposes, it is the *relative* heights which are of consequence, not the absolute heights.

QUESTIONS FOR PRACTICE.

1.—In sketching down the watershed of a spur, the following observations were made—

Slope	3°	for a	distance of	445	yards,
Then	6°	,,	,,	288	,,
,,	8°	,,	,,	276	,,
,,	12°	,,	,,	136	,,

Mark the position of contours. Scale $\frac{1}{10560}$ V.I. 20 feet.

2.—Plot the following observations, and show the shape of a bit of each resulting contour :—

A to B,	bearing	65°,	distance	130	yards,	slope	15°
B to C,	,,	40°,	,,	95	,,	,,	10°
C to D,	,,	350°,	,,	132	,,	,,	8°

From D on the same bearing, a rise of 3½ contours at a slope of 8° to the crest of a knoll; then 40 yards across the knoll, whence angle of depression to a stream, 192 yards distant, 3°. Scale, 12 inches to a mile, V.I. 10 feet.

3.—Draw 6 lines radiating from a point A, making angles with each other in succession from the left of 40°, 43°, 35°, 31°, and 31°. Let each line be divided into 4 parts—AB, BC, CD, DE. Let the scale be 12 inches to a mile, V.I. 10 feet. Then, through the points B, C, D, E, draw four contour lines from the following data :—

On line	No. 1	slope AB is	1½°,	BC is	6°,	CD is	10°,	DE is	12°
,,	No. 2	,,	1½°,	,,	2°,	,,	2°,	,,	1°
,,	No. 3	,,	3°,	,,	4°,	,,	4°,	,,	1½°
,,	No. 4	,,	1½°,	,,	2°,	,,	1½°,	,,	1°
,,	No. 5	,,	2°,	,,	4°,	,,	4°,	,,	3°
,,	No. 6	,,	3°,	,,	5°,	,,	6°,	,,	7°

4.—By means of a few contours, represent a tract of hilly country, about 1 mile square, containing the following features, one or more of each :—

A plateau, a ridge, a spur, a col, an underfeature, and a stream flowing in a south-westerly direction into the sea. General direction of the coast-line, North and South; cliffs 60 feet high at the northern end of it. Scale $\frac{1}{10560}$ V.I. 20 feet.

5.—State, showing the work, what is the steepest, and what the easiest slope represented in the above sketch, and give the corresponding gradients.

6.—From a range of heights of which the general direction is east and west, several spurs run southwards to a river, which flows in an easterly direction to the sea, and is joined on its way by several streams, coming down between the spurs referred to. From the subjoined data, give a contoured plan of the ground :—

A is the highest point of the range. It is 258 feet above the sea; 58 feet higher than another point B; and 750 yards due west of it. From B, the slope of the hillside in a direction due east is 10°, and ends abruptly at C in cliffs 100 feet high. D is a point on the coast-line at the mouth of the river. Its height is O, and its bearing from A is 137°, and from C, 190°. E is an underfeature, 30 feet higher than the col connecting it with the main hill. Observations taken at E :—bearing to A, 39°; to D 112°; angle of elevation to A, 5°. F is another underfeature, 105 feet above the sea. The bearing from F to A is 10°, and from C to F, $243\frac{1}{4}$°. The river falls 80 feet in a *winding* distance of 2,200 yards, between a point K up-stream and its mouth D. But the direct distance from K to D is only 1500 yards, and K bears 280° from D. The general direction of the coast-line is north and south. Three tributary streams, G, H, and L, all about the same length, flow nearly parallel to it. The head of the stream G is 250 yards due south of A, and 158 feet below that point. Its average fall in a distance of 600 yards, when it joins the river, is 1 in 45. It flows midway between the underfeatures E and F. H is about 250 yards east of G, but its average fall is twice as great: and L lies about midway between H and the sea. Scale, 6 inches to a mile. V.I. 20 feet.

7.—Lay down the following intersection of stations: scale, 6 inches to a mile :—

Base : AB—800 yards long.

$$\text{At A, bearing of } \begin{cases} \text{B—}90^\circ. \\ \text{C—}40^\circ. \\ \text{D—}150^\circ. \end{cases}$$

$$\text{At B, bearing of } \begin{cases} \text{C—}315^\circ. \\ \text{D—}235^\circ. \end{cases}$$

A and B are both 250 feet above the sea, and are situated on the top of a hill. C and D are the summits of hills. At A the angle of elevation of C is 3°. D is 270 feet above the sea. The sea is about 500 yards west of A, north of C, east of B, and south of D. Sketch the ground in contours at 20 feet V.I.

8.—ABCD is a metalled road, with fences, on an island ; A and D are on the coast. M and N are two hill-tops.

At A, bearing of M, 50° : angle of elevation, 6°.
,, bearing of B, 85° : angle of elevation. 3°.
,, bearing of N, 120°: angle of elevation, 5°.

AB = 572 yards.
BC = 191 yards.
CD = 700 yards.

At B, bearing of C, 60° : angle of depression, 2°.

$$\text{At C, bearing of } \begin{cases} \text{M, }311^\circ. \\ \text{D, }90^\circ. \\ \text{N, }209^\circ. \end{cases}$$

The sea is about 500 yards north of M, and 600 yards south of N.

Draw the island in contours, at 20 feet vertical intervals. Scale : 6 inches to a mile.

What is the angle of elevation of N from D?

CHAPTER X.

SHADING HILLS.

After ground has been contoured, the hill features may be shaded. The chief object of doing this is to develop them; make them, as it were, stand out in relief, so that hills and valleys may be distinguished at a glance. Relying on the contours alone, it might sometimes be a little difficult to do this. The shading removes this difficulty, and by heightening the general effect, gives a much more graphic idea of the ground than would ever be conveyed by the contours alone. Shading used to be effected by *hachures*, pen, or pencil-strokes, between the contours, drawn thick, black, and close together, to represent steep slopes; and thin, light, and far apart, to show gentle slopes. The *Scale of Shade* was a scale which defined the number and thickness of the strokes for each degree of slope. If the hachuring was theoretically perfect, therefore, the slope at any point on a map should have been recognisable from the depth, or lightness, of the shade. Such excellence was, however, rarely attained. The contours were, and always will be, a more reliable guide to the steepness of the slopes, than any shading. But the hachuring, while it failed itself to indicate the slopes satisfactorily, had a tendency (especially if the ground represented was steep) to obscure the contours, and sometimes other important details. Further, it was a method hopeless of acquirement by men without aptitude, and disgusted those who in spite of want of natural talent were compelled to learn it: and finally, it involved a great expenditure of time and labour by those even who were skilful in it. For these reasons, it was practically abandoned for military purposes, and its place was taken by what is technically termed "*shading in mezzo-tint*," or more commonly, "*stumping.*" The advantages of this method as compared with hachuring, are:—

(*a*) Anyone can learn it.

(*b*) It does not obscure the contours, or other details.

(*c*) It develops the hill features very effectively.

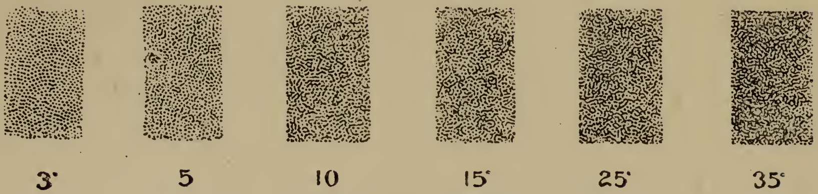
(*d*) It takes about *one-twentieth* of the time occupied by the old method.

(*e*) It is much easier by its means to secure uniformity of shade in different sketches.

These are all important advantages. The principle of using deep shades for steep slopes, and light shades for gentle ones, must, of course, be still carried out. To give an idea of the depth of shade proper for particular slopes, and to secure uniformity as far as possible, a "scale of shade" was formerly issued by authority, a copy of which is given in *Plate* XXX. The shading may be effected in various ways. The simplest is with a soft B B pencil, to make a few strokes between the contours at points where a deep shade is required. The pencil must be pressed very lightly on, otherwise indelible marks will be made. Then with a leather stump, or a bit of chamois leather folded into a pad, or the finger of a buckskin glove, rub with a steady, but rather quick, motion, backwards and forwards over these strokes, until they are obliterated, and in their place, a uniform dark shade produced free from smudges and cut-lines. This can now be gradually worked towards the lighter parts, until the steep and gentle slopes are neatly and naturally blended. More black pencil can be added as required, and india-rubber can be used to lighten portions which are too dark, and to clean up edges, &c., which have been invaded by the shading. Another method is to scrape a little black chalk, or soft lead pencil, into a saucer, and dip the stump into it when colour is required. This is perhaps a better way than the other. It is a good plan to "fix" the shading by pouring a thin wash of gum water over it. This must be done before any paint is applied to the sketch. The contours should be shown in brown or red continuous lines if using paint or chalk, or, if these are not available, by a chain dotted black line.

The great objection to all systems of brush or stump shading is that it is next to impossible to reproduce it in the field. Officers should, however, understand the hachure and other shading systems, as the hill features on many small

PLATE XXX.



SCALE OF SHADE

scale ordnance maps of the United Kingdom, India, &c., and of foreign countries, are shown by one of them.

With the new system of V.I.'s, the contours are brought close enough together themselves to give a good shade effect.

CHAPTER XI.

SECTIONS.

A section is a representation of the surface that would be exposed if a hill were cut through in any given direction by a vertical plane. A section, therefore, shows heights and depressions, and the object of drawing one might be to decide a question of relative height between two points on a map: or to say whether the ground between them was of such a nature that one could, or could not, be seen from the other. There are, however, quicker ways of deciding these questions than by drawing a section; so generally a section would only be required to test one's ability to understand a contoured plan. Everyone, therefore, should be able to draw one if asked to.

In drawing a section it is customary to exaggerate the heights. This is done because the heights are so small in proportion to the distances, that if both were represented on the same scale, the slopes would not be appreciated. They would appear almost as nothing. For instance, on a scale of 6 inches to a mile, the vertical interval between contours is only 20 feet. This, even on such a large scale, is almost an inappreciable distance, and if we draw our section lines only 20 feet apart, we should get no adequate idea of the slopes. So what is called the vertical scale, is always exaggerated 5 or 6 times, or more, according to circumstances; and when a section is required, the exaggeration is always stated in the conditions, thus:—Vertical scale, $\frac{1}{2112}$ or $\frac{1}{1760}$, &c., as the case may be; or, H : D : : 5 : 1, or 6 : 1, which means, Heights to Distances, as 5 to 1, or 6 to 1.

To draw a Section on any given line.—The first thing to do is to settle how far apart the section lines will be, and then draw them, as many as you think will be necessary. Make the bottom one a little thicker than the others, call it DATUM, and mark it O, and those above it 1, 2, 3, 4, &c., in succession. Suppose the scale of the map is 6 inches to a mile, and vertical intervals 20 feet: and for the section, it is stated, H : D :: 6 : 1. This means that the heights are to be exaggerated 6 times; and so the section lines are drawn 20 × 6 = 120 feet = 40 yards apart, taken off the scale of 6in. to a mile. Next, take a sheet of paper, lay its edge exactly along the line on which the section is required, and with a pencil tick off every contour cut by it, and number them, marking the lowest contour 1 and taking care that each time the same contour cuts the line it gets the same number. Now transfer these marks to the Datum, and on each of them raise a perpendicular to meet the corresponding section line. Join the heights so found, and you have your section. (*Plate* XXXI., *Figs.* 1 & 2.)

If preferred, the numbering, 1, 2, 3, &c., of the contours and section lines, can be done in pencil, and as soon as the section is drawn, these numbers can be rubbed out, and the absolute heights substituted. (*Fig.* 3, *Plate* XXXI.)

Drawing sections requires care. In following a line across a map, particularly if it crosses underfeatures, cols, &c., a beginner is sometimes puzzled to say whether he is going up or down hill. A little attentive practice will soon overcome this difficulty. The watercourses will be found an unfailing guide. By observing which way the streams flow, mistakes can almost certainly be avoided.

QUESTIONS FOR PRACTICE.

1.—Draw a section on the line C D, *Plate* XXXI. Vertical scale $\frac{1}{1760}$.

2.—Draw a section on the line E F, *Plate* XXXI. Vertical scale 80 feet to an inch.

3.—The Plan scale being 4 inches to a mile, V.I. 30 feet, a section is required, H : D :: 10 : 1.

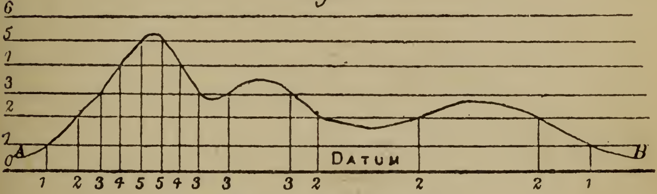
Explain how the section lines will be drawn.

PLATE XXXI.

Fig. 1.

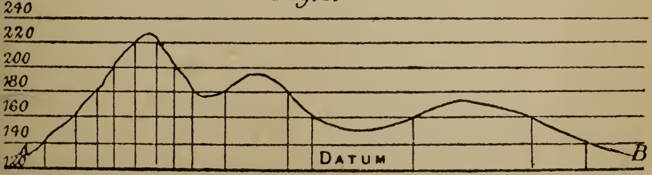
Scale $\frac{1}{10560}$. V.I. 20′.

Fig. 2.



Section on AB. HD as 6:1.

Fig. 3.



Section on AB. H:D::6:1.

CONCLUDING REMARKS.

All the instruments, and the processes, commonly resorted to in making a military sketch, have now been simply described. It only remains to remind the reader that a little practice in the field is worth volumes of theory: and that the best way of testing one's proficiency is not by answering book questions, but by going out to make sketches under varying conditions as to ground, time, and the instruments employed. Let no one be discouraged because their first attempts are failures, or because the time taken over them is out of all proportion to the results achieved. Everything must have a beginning. We are not all equally clever with our pencils and pens, nor all equally gifted with that *coup d'œil militaire* which enables some men to take in at a glance the salient features of a country, and appreciate its tactical possibilities. But practice and perseverance can effect a great deal; and it must ever be remembered that a highly-finished, artistic representation of the ground is not what is wanted. Any tendency to indulge in pictorial effect should be sternly repressed, for it is very likely to be at the expense of truthfulness, and therefore misleading.

The chief points of importance in a military sketch are:—

(*a*) That it shall faithfully represent the ground.

(*b*) That it shall be unmistakably clear; and

(*c*) That it shall be executed with reasonable rapidity.

The first two of these conditions are comparatively easy of fulfilment, and the third will come with practice.

CHAPTER XII.

MILITARY MAPS EXPLAINED.

Many of the questions, and some of them the most important ones, connected with the proper understanding of military maps, have already been discussed incidentally in the course of the preceding pages. For instance, the system on which maps are ordinarily contoured has been thoroughly explained, and anyone who has attentively read *Chapter* VIII., should not have now the smallest hesitation in saying what is the slope, or gradient, at any given spot on a contoured plan: or in answering any question connected with heights and distances on it. It only remains, therefore, to give a few practical hints by which the method of examining, and understanding, a map may be, so to speak, systematised and made easy.

When a contoured plan is about to be examined, there are three preliminary points to attend to before commencing to answer questions in connection with it. They are:—

1.—What is the scale of the map?

2.—What is the V.I.

3.—Where is the north point?

Regarding the scale: It is pretty sure to be drawn and figured on the plan: or the R.F. may be given: or it may be revealed by a road having milestones along it, &c., &c. There must be something to show it, and it must be found out before anything else can be done. Having settled, then, what it is, try to impress upon the mind the distance by the scale representing one mile, or half a mile, &c., so that when examining the map a fair estimate may be made of distances between points on it, without constant reference to the scale. Next, the vertical intervals must be ascertained, and "a scale of slopes" at once constructed (*See p.* 151, *Fig.* 54), if one is not already shown on the plan; otherwise in estimating slopes, serious mistakes may be made.

Finally, see where the north is. Ascertain the direction of both true and magnetic north, for sometimes they vary considerably.

It may be assumed that on a map where no north point is shown, the sides of the map are approximately true north.

These preliminaries being settled, we are prepared to answer any questions on the map that may be put. The most common and practical ones which may arise are:—

(*a*) Questions regarding slopes, and their practicability for the manœuvres, or movements of troops.

(*b*) Questions regarding the gradients of roads.

(*c*) Questions regarding the relative height of points, and the view obtainable from any given spot.

Questions coming into classes (*a*) and (*b*) have already been fully discussed, and illustrated in *Chapter* VIII. It is only necessary to say here to what extent particular slopes are practicable for each of the three arms.

1/4 15° is the *extreme* limit of slopes admitting of manœuvres. 1/2 Slopes between 15° and 30° may be ascended and descended singly by infantry and cavalry; but by the latter with great difficulty; and slopes of over 30° require to be *climbed* up.

The following detailed table will be found useful:—

Slopes up to 5°	Are practicable for all arms. Cavalry will charge more effectively *up hill* than down. Artillery fire is more effective down hill than up.
Between 5° and 10°	Close movements for infantry are difficult. Cavalry can only charge *up hill* a short distance. Artillery moves with difficulty; its effectual and constant fire ceases. A slope of 8° will almost stop baggage waggons without extra horses.
Between 10° and 15°	Infantry can only move a very short distance in order. Cavalry can only trot a short distance up hill, and walk down. Artillery moves with great difficulty; fire ceases entirely.
Between 15° and 20°	Infantry cannot move in formed bodies. Cavalry can ascend at a walk, and descend obliquely.
Between 20° and 25°	Infantry can only move in extended order. Light cavalry may ascend and descend obliquely one by one.

Between 25° { Infantry as before, but very slowly.
and 30° { Cavalry as before, but with great difficulty.

Slopes over 30° may be climbed up by men using their hands.

We come now to questions which may be included in class (c). As to the relative height of points, there should never be any difficulty in deciding, as it is simply a question of taking any convenient spot for a datum, and counting the number of contours that each is above it, and comparing them. Simple as the matter is, however, mistakes are constantly made through one contour being counted twice over, or through an intervening underfeature interrupting the continuity of the counting. A little practice is all that is wanted to correct this, and with a contoured plan before him, the student should constantly set himself questions involving the counting of contours, till he is confident he thoroughly understands how to do it.

As regards the view obtainable from any given spot, there is something to be said. The question will generally resolve itself into one of whether from a given spot some other given spot is visible or not. This could of course be ascertained by making a section of the ground between them, but this would be a long and clumsy method of deciding the point, and should never be resorted to. There are three other ways in which such a question may be answered, each of which is described below.

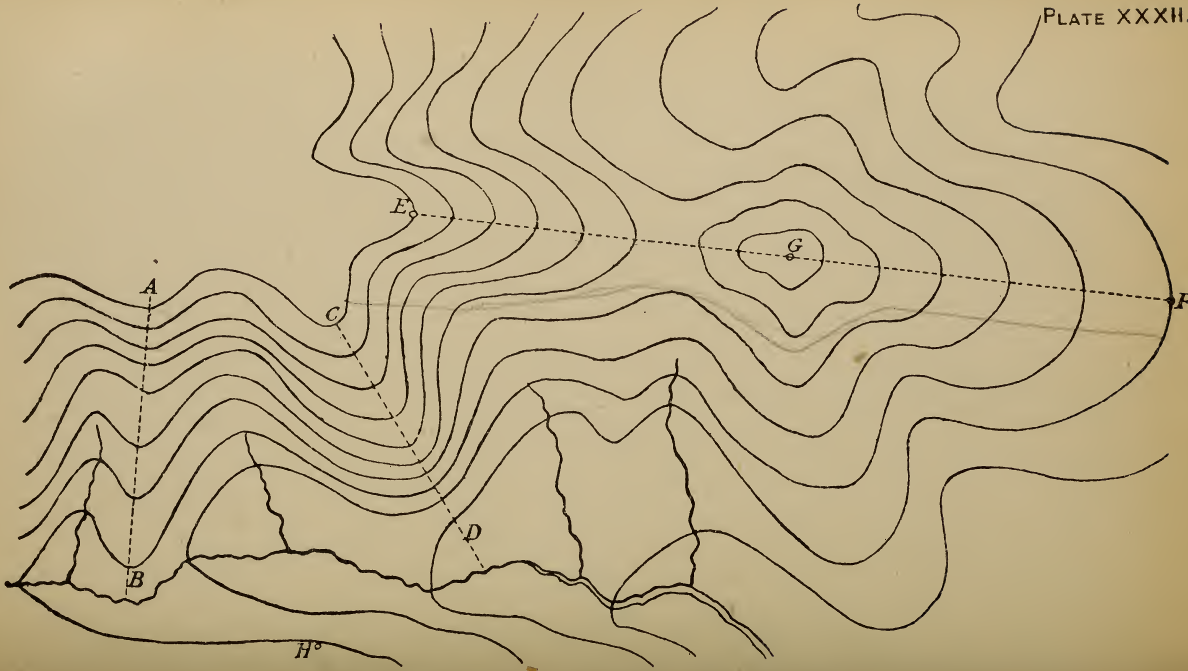
1stly.—It can be ascertained whether the general section of the ground between the points is concave, or convex.

2ndly.—What is called *a hand sketch* of the section can be made.

3rdly.—The point may be decided by an application to it of the principle of similar triangles.

The first of these methods has already been touched upon in *Chapter* VIII. If the general section of the ground between the two points concerned is concave, they are

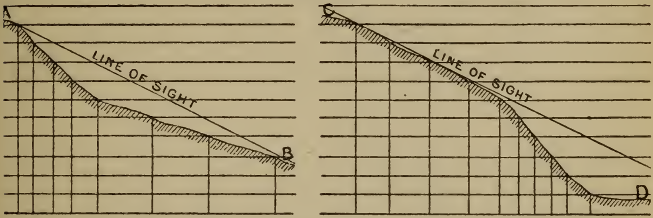
PLATE XXXII.



Scale 6 inches to 1 mile. V.I. 20 feet.

visible to each other: if convex, they are not. If the ground between the points is one continuous slope as at A B, or C D, *Plate* XXXII., an inspection of the contours shows at once whether the section is concave, as on the line A B, or convex, as on the line C D. In the first case, the upper part of the slope is steep, the contours there being close together, and the lower part is gentle, the contours being far apart; therefore the section is concave, and B is visible from A. (*Fig.* 63). In the latter case the conditions are exactly reversed: the upper part of the slope is gentle, the lower part steep. Hence the section is convex (*Fig.* 63), and D cannot be seen from C.

Fig. 63.



SECTION ON A. B. (PLATE XXXII.) SECTION ON C. D.

But if the ground between the two points is not one continuous slope, then a small calculation becomes necessary. If the points are situated on the opposite sides of a valley, like G and H, *Plate* XXXII., of course they are visible to each other; but if another hill, or underfeature, comes between them, then it is a question of whether it is high enough to intercept the line of sight from one point to the other, or not. If it is, then it makes the general section convex: if it is not, then the general section is concave. To decide this point, compare the gradient of the line of sight from the higher of the two points to the intervening point, with the gradient of the line of sight from the intervening point, to the lower of the two points. If the former is steeper than the latter, the general section is concave, and the two points are visible to each other: if the reverse is the case, the general section is convex, and they are not. This explanation seems long and complicated on paper. In practice it will be found extremely simple. For example, referring again to *Plate* XXXII.

Is the point F visible from E? The intervening point here is the underfeature G. Now E is four contours, or 80 feet higher than G, and the distance is 620 yards; therefore, the gradient is $\frac{80}{620 \times 3} = \frac{1}{23}$. But G is 5 contours, or 100 feet higher than F, and the distance is 600 yards, therefore the gradient is $\frac{100}{600 \times 3} = \frac{1}{18}$. This is a steeper gradient than $\frac{1}{23}$, therefore the general section is convex, and F cannot be seen from E.

The hand-sketch method.—This is a very simple and sure method, and is best illustrated by an example. We will take the same case as before: *Is F visible from E?* (*Plate* XXXII). Draw a datum line, taking for a datum the level of the lower of the two points concerned; viz.: F. On it prick off the exact positions of E and F, and of the intervening point G. (*See Plate* XXXIII., *Fig.* 1). On E and G raise perpendiculars, marking that at E, 9 units high, E being 9 contours higher than the datum F: and that at G, 5 units high, G being 5 contours higher than F. Then through the tops of these perpendiculars, draw the line of sight, and it will show at once whether the distant point F is visible, or not. In this case, it is not, for the line of sight passes considerably over it.

We now come to the 3rd method, and will still use the the same example to illustrate it. This method is based on the principle, that in similar triangles the sides are proportional, and therefore the bases must bear the same proportion to each other as the heights. If they do not the similarity does not exist. In the case before us, again taking F as the datum, the heights are respectively, G 5 contours, and E, 9. Therefore, the base, or horizontal distance F G, ought to be $\frac{5}{9}$ths of the whole distance, F E. On examination, it is found that it is *not*: it is less; therefore F is *not* visible

PLATE XXXIII.

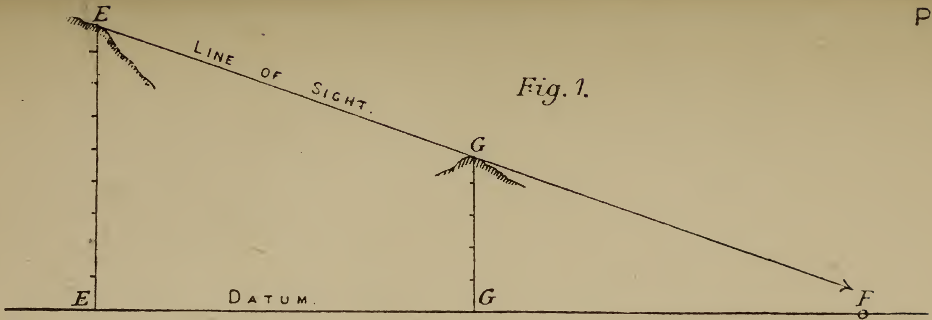


Fig. 1.

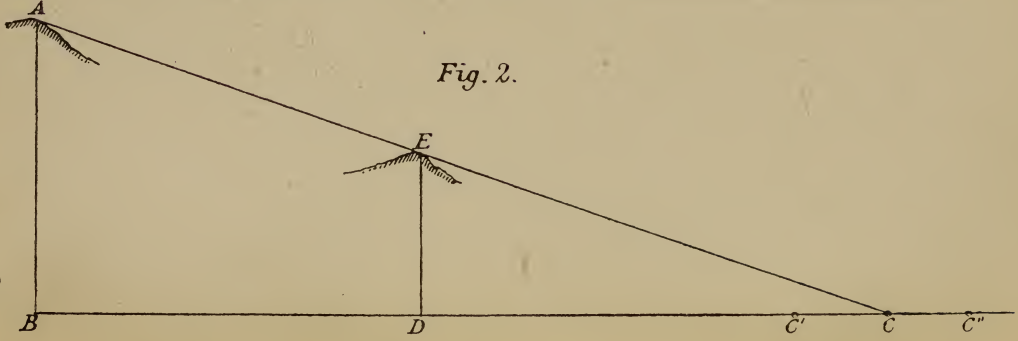
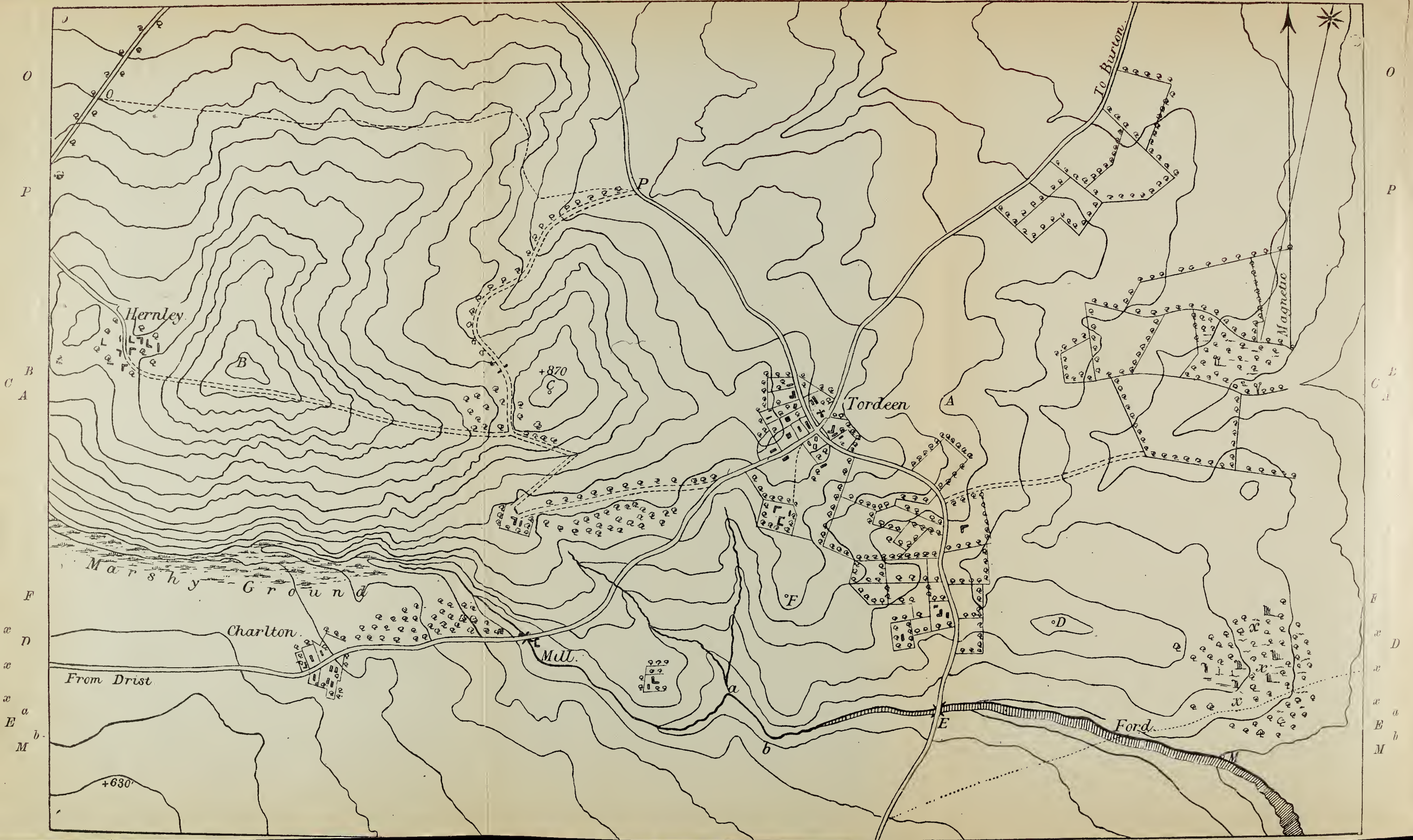


Fig. 2.

Plate XXXIV.


O
P
C
B
A
F
x
D
x
x
E
a
b
M
O
P
To Burton
P
Hernley
B
+870
C
Magnetic
Tordeen
A
Marshy Ground
F
Charlton
Mill
D
From Drist
a
E
b
Ford
x
x
x
M
+630'
O
P
C
E
A
F
x
D
x
x
a
E
b
M

from E. If it *was* $\frac{5}{9}$ths. of the whole distance, or *more* than $\frac{5}{9}$ths of it, then F *would be* visible from E.

This will be seen at once if the reader will refer for a minute to *Fig.* 2, *Plate* XXXIII. There it is evident that A B C and E D C are similar triangles, and therefore the base C D bears the same proportion to the base C B, that the perpendicular D E, bears to the perpendicular B A; and if C E A were points on the ground, it is clear that C could be seen from A. But if the base C D was *less* than its proper proportion of C B—for instance, if C was at C′—then the line of sight, A E, would pass above it, and it would not be visible. On the other hand, if the base C D was longer than its just proportion—if C was at C″, for instance—then the line of sight, A E, would strike below it, and it would be seen.

It only remains now to give examples of questions in reading maps. The following questions all refer to *Plate* XXXIV., and should be attentively worked out by the Student, who, with the aid of the accompanying explanations, should have no difficulty in understanding them.

EXAMPLES.—(*See Plate* XXXIV.)

1.—*What is the V.I. of the contours?*

On examining the map carefully, a contour is found marked 870 feet, and another (in the left hand bottom corner) marked 630 feet. The difference therefore in the height of these two points is 240 feet. Now take and convenient point as a datum for counting, say the Mill Bridge, and I find that one of these points is 11 contours above it, and the other only 7. Here is a difference of 4 contours, and the difference in height being 240 feet, each contour must be 60 feet. (*See page* 143).

2.—*Can E be seen from C?*

No, it cannot. The spur F intervenes, and is high enough to intercept the view. A hand-sketch will show this at once, and it will be practice for the student to make one. Meantime, it may be noted that in a distance of about $2\frac{1}{2}$ inches, there is a rise of 7 contours from F to C, while in a distance of about $1\frac{1}{2}$ inches, there is a rise of 5 contours from E to F. This is a steeper rise than the other, therefore the general section is convex, and E is invisible.

The same result is arrived at by observing that F is 5 contours and C 12 contours above E, and that E F is *not* $\frac{5}{12}$ths of the distance E C, and therefore E is *not* visible from C.

N.B.—If the question had been: *Would troops crossing the bridge at E be visible to a sentry at C?* The answer would be "yes." But the hand sketch only will show it. If it is drawn carefully it will be seen that though the point E cannot be seen from the point C, yet the line of sight passes so little above it, that, making allowance for the height of the troops and the height of the sentry's eye above the ground, the probability is that men crossing the bridge would be visible from C. This point must not be lost sight of in answering questions of this kind.

3.—*What parts of the stream can be seen from C?*

No part of it can be seen from its source up to the re-entering bend *a*, for the slopes down to it, up to that point, are clearly convex in section. The small bit *a b* can be seen, as the general character of the section on the line C *a b* is concave. Beyond this the stream is lost sight of until shortly before the ford is reached, from which point it is visible from C until it runs off the map. The spur F is the only point that might intercept a view of the ford. It is 6 contours above it, while C is about 13; and, as the distance from the ford to F is well over $\frac{6}{13}$ths of the whole distance between the ford and C, those points must be mutually visible. Similar tests will show that the stream is visible all the rest of the way within the limits of the map.

4.—*The Spire of Tordeen Church is just visible from M (right hand bottom corner of map). What must its least height be, vertical intervals being 60 feet?*

Draw a line joining M and the Church, and then observe that the hillock D is the intervening point. D is 4 contours, or 240 feet above M, and 1.65 inches from it—the actual distances in yards are not required here—and the Church is 7 contours, or 420 feet above M, and 4.15 inches from it. From these data make a rough diagram (not to scale), as under. Here we have two similar triangles, whose bases are known, and one perpendicular, D · hence the other one,

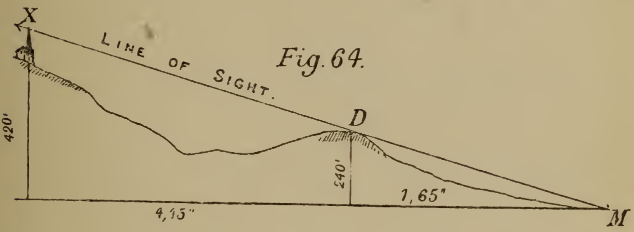


Fig. 64.

x, can be found at once from the following proportion :—

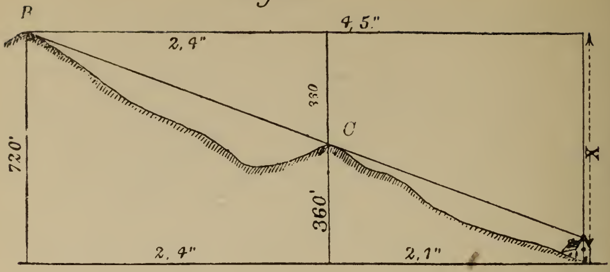
$$1.65 : 4.15 : : 240 \text{ ft.} : x \text{ ft.}$$

from which $x = 604$ feet. Subtract 420 feet, the height of the ground, and the remainder, 184 feet, is the required height of the Church.

5.—*A chimney on the house just north of the Church can be seen from B. What must be its height above the ground ?*

This question is something like the last ; but when the observation is from high ground to a lower level, the figure used is a little different. In this case C is the intervening point. It is 6 contours, 360 feet, above the datum, and 2.1 inches from it. (It may be noted here that the lower of the two points concerned is *always* taken for the datum.) B is 12 contours, 720 feet, above the datum, and 4.5 inches from it, and 2.4 inches from C. From these data we construct

Fig. 65.



the following figure, from which x is calculated, thus :—

$$2.4 : 4 5 \quad :: \quad 360 \text{ ft.} : x \text{ ft.}$$

from which $x = 675$ feet. But the whole height above the datum is 720 feet; therefore the height of the chimney must be 45 feet.

6.—*A cross road is to be made from O to P, the shortest line to be followed, and any gradient steeper than 6° to be avoided. Mark it out on the map.*

6° is a gradient of 1 in 10, that is in a rise of 60 feet (the vertical interval between the contours), the base must be 600 feet, or 200 yards. This determined, the road is traced (*See dotted line from O to P*) by eye, taking care that throughout its length this proportion is nowhere exceeded.

7.—*Some Troops are lying down on the slopes to the east of D, marked x x x. Supposing no trees to be there, could they be seen from F? And if a Battery was in action at F, firing in the alignment F D, could it search those slopes with its fire, or not?*

The slopes in question could not be seen from F. The hillock D is in the way. From D to F there is a rise of 2 contours in about 2 inches. But from x x to D there is a rise of nearly 3 contours in about $1\frac{1}{2}$ inches. The general section therefore is convex, and the slopes are out of sight. But they *can*, nevertheless, be searched by the fire of a battery at F.

In ordinary country no reverse slope can give troops absolute immunity from fire, as field gun shrapnel may have a searching power of as much as $\frac{1}{3}$, while howitzer shrapnel may considerably exceed $\frac{1}{1}$.

QUESTIONS FOR PRACTICE.—(PLATE XXXIV.)

N.B.—In answering all the following questions, it is to be assumed that the scale of the map (*Plate* XXXIV.) is 6 inches to a mile, and the vertical intervals 20 feet, except when it is specially stated otherwise :—

1.—Assuming the contour round D to be 260 feet above the sea, mark the highest and lowest contours on the map with their proper heights.

2.—A train of baggage waggons has to move from Tordeen to Hernly by the cross-road shown on the map. How would its progress be affected by the gradients encountered ?

3.—Can the ford be watched effectively by a sentry posted at B ?

4.—In walking along the road from Drist to Burton, if no trees or houses existed on the map, at what points would you be invisible to an observer stationed at C ?

5.—What is the average fall of the river within the limits of the map ?

6.—How high would you have to ascend vertically above O, before the ford would be visible to you ? The ford is 10 feet lower than the contour next above it, and the summit of C is 10 feet above the nearest contour.

7.—A flagstaff planted at C is just visible from the centre of the bridge at E. What must be its least height, making no allowance for the height of the observer's eye above the ground ?

8.—The top of a tree at A (east of Tordeen) can be seen from B. What must be its height, assuming the contours to be at vertical intervals of 60 feet?

9.—Draw a section (right across the map) on the alignment C E. Vertical scale, 100 feet to an inch.

CHAPTER XIII.

RECONNAISSANCES, REPORTS, AND SUPPLIES.

Reconnaissances may be of two kinds:—

(*a*) Those undertaken of the enemy, to ascertain his strength, dispositions, &c.

(*b*) Those made with the view of collecting information about the country, and its resources.

In a reconnaissance, to be really successful in execution, and valuable in results, the following conditions are necessary :—

(*a*) Distinct orders as to what is required.

(*b*) Some aptitude with pen and pencil.

(*c*) Ability to ride.

(*d*) Previous careful study of the best maps of the district.

It is not intended to convey that the fulfilment of all these conditions is indispensable, but it is obvious that they are all in the highest degree desirable.

To begin with (*a*). A reconnaissance may be ordered for one of many objects. But whatever may be the purpose for which he is sent out, an officer before starting, should be sure that he clearly understands his instructions. So only can his duty be efficiently and intelligently performed. If he has no definite instructions; or having them, allows himself to wander away from them after details which are not required, he will surely fail in his mission, and waste his time. For instance, if ordered to reconnoitre a river with a view to find some way of crossing it, he would be wasting his time if he stopped to examine and report upon the villages *en route* to it, and the accommodation and supplies available in them. It is therefore of the utmost importance to have clear instructions before setting out; to thoroughly understand them ; and to confine your attention strictly to them until your task is completed.

Secondly.—Some aptitude with pen and pencil is necessary, The reconnoitrer has a report to submit as well as a sketch, and just as with the latter there is a tendency (particularly with good draughtsmen) to make pretty pictures at the expense of accuracy; so with the former, there is often a tendency to be diffuse and elaborate in description at the expense of clearness. This fault must be guarded against. Reports cannot be too succinct, provided they are clear. Everyone cannot express in a few well chosen words just what he wants to say, but to do so in the fewest words possible should at least be everyone's aim. The handwriting should be extremely legible, and the names of places, or persons, must be *printed* in *plain block capitals*, thus: WOOLWICH, ROBERTS, to prevent the chance of a mistake in regard to them. If a name has a peculiar pronunciation it should be explained, thus:—KIRKCUDBRIGHT (KIR-COO-BREE). The sketch itself should carry as much as can be shown on it clearly, and without confusion. What is already shown by the sketch, need not, of course, be reiterated in the report, but attention may be directed to points of particular importance. Report and sketch must supplement each the other. The two together should give graphically, but as briefly as may be, just the information required, and no more. There is no particular form for the report. It is generally written on foolscap, in the form of a memorandum, with marginal headings to catch the eye, such as *rivers*, *bridges*, *communications*, *the flanks*, *the country generally*, *&c.*, *&c.* In the reconnaissance of a road, there will often be room *in the margin of the sketch* for all the information necessary. In such cases, report and sketch will be handed in on the same piece of paper, the marginal remarks being connected, (when necessary) by a pencil line with the objects on the sketch to which they refer.* The necessity of brevity in reports has been insisted on, but reticence may occasionally be carried too far. Therefore, while avoiding anything like prolixity, be careful to omit nothing that may be of real consequence.

Referring to the operations in Afghanistan in 1879–80,

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* A form of road report is given at the end of this chapter, but only the headings required should be reported on.

Lieut.-General Sir Samuel Browne writes:—"Often the information submitted was far too scanty. It is not too much to say that in ordinary reconnaissances it is only necessary that the sketch should sufficiently illustrate the report, whereas in practice officers frequently devote all their time to the sketch, and then append only most meagre notes." These are suggestive remarks.—*Verbum sap.*

Thirdly.—It need not be explained that often the most valuable reconnaissances are those which are made at a distance from support, in the neighbourhood of the enemy, possibly under his observation, and always with the probability of his sudden interference. Under these circumstances the Reconnoitrer must be well mounted and able to ride, and and to sketch (if needs be) on horseback, if he expects to do useful work.

Finally.—While it is desirable that every officer proceeding on service should be provided with the best maps procurable of the scene of operations, in order that he may intelligently follow what is taking place, and the movements of troops going on round him, it is absolutely necessary that Staff Officers, and all those who may possibly be employed on reconnaissance duty, should, by the careful study of such maps, make themselves thoroughly acquainted with the country in their vicinity. They should know familiarly the position of the chief towns and villages, their distances apart, the roads and railways connecting them, the rivers and heights in their neighbourhood, and their population and resources, &c., &c. All this, and much more useful information, can, as a rule, be gleaned beforehand from maps and books; and it is plain that one who is already in possession of such facts will be able to carry out any duty with which he may be intrusted with more boldness and confidence, and consequently more thoroughly, than is possible for a man who starts in ignorance of them all.

Some remarks on the method of using a map in the field will be found at the end of this chapter.

The amount and nature of the information collected by a Reconnoitrer must depend upon many things—the instructions received, the time available, the distances to be traversed, the difficulties in the way, and in no small degree upon the aptitude, endurance, and enterprise of the individual, A reconnaissance may be undertaken to report upon a Position, a Road, a River, a Railway, &c., &c. The points to which attention should be directed in each case are given below; but experience and opportunity, or the conditions and object of the reconnaissance, will decide on each occasion which of them may be disregarded, or to which should be given special prominence.

RECONNAISSANCE OF A POSITION.

This may be considered under three heads—

(*a*) It may be the enemy's position which is to be reconnoitred and reported upon.

(*b*) Or, the general nature and capabilities of the ground in a particular neighbourhood, with a view to its occupation for defence, may have to be ascertained.

(*c*) Or, a position may be required, to be held by a small force of a given strength: for instance, by a Rear Guard.

In the first case the duty would probably be assigned to Staff Officers; but it might fall to anyone's lot to undertake it, particularly to the lot of Officers of Cavalry scouting in advance of the Army. The only sketch that under such circumstances could be made of the position would be a freehand or landscape sketch, or one made with a range finder and plane table or prismatic compass; for near approach to the enemy's line would certainly be difficult, and probably impossible. The chief interest, then, would lie in the Report, and the following are some of the principal points that should be noticed in it:—

Any landmarks, such as heights, villages, &c., indicating exactly the locality and the extent of his position; the approaches to it, their nature, practicability, &c.; are any of them under cover by reason of woods, hollows, &c.? How are they apparently watched or guarded? What are the natural obstacles to be passed or overcome? Are any artificial ones noticeable? Is the position entrenched? How are the flanks posted? Are there any means of getting round them? Is the position a commanding one with reference to the surrounding country? Is the position of any batteries known? Are any posts, villages, farmsteads, &c., held in, or in advance of, the main line? What appear to be the weak points of the position? And, finally, is the service of the outposts vigilant and effective?

Cases (*b*) and (*c*) differ from each other chiefly in this respect: In the one the strength and composition of the force that will occupy the ground selected are not known; in the other they are. In the latter case, therefore, regard must be had to the special requirements of the case. It is no use, for instance, to find a position impregnable if held by 5000 men, when it is known that 3000 at the outside will be available for its defence. Similarly, it would be waste of time to examine and report upon ground, whose chief characteristic is that it is open and favourable to the action of Cavalry, when it is certain that the defending force will be altogether deficient in that arm. The number of men who can properly occupy any given position depends a good deal upon the nature of the ground. Some places are naturally very strong, or can be made so with very little labour. Others are open, exposed on every side, possess no strong points, and are proportionately weak. Such positions, if they must be held, require, of course, many more men to defend them. No rule, therefore, can be laid down as to the exact number necessary; but, as a guide, it may be assumed that to occupy one mile of front 2 battalions at full war strength should ordinarily be sufficient, exclusive of the general reserve.

The conditions then for (*b*) and (*c*) are almost the same; only in case (*c*) they must be guaranteed, while in case (*b*) the character and capabilities of the position indicated, must be reported on as they are found; and it will be for the officer to whom the information is submitted, to decide whether he can advantageously occupy it or not. The following are some of the conditions to be sought for in a good defensive position, and they are those, therefore to which the reconnoitrer's attention should be directed.

Probably in no case would they all be attainable, but, of course, the more of them that can be secured the better :—

1. The locality chosen should satisfy the plan of operations.

2. The extent of the position should be suitable to the strength of the defending force, *i.e.*, there should be enough men and guns to fulfil the object of the commander, the maintenance of the entrenchments, and the delivery of a decisive counter-attack.

3. A clear field of fire over the country in front and on the flanks, and no dead or unseen ground within effective range.

4. Flanks resting on ground naturally strong or made so artificially.

5. Good cover.

6 Good artillery positions, with a clear field of fire to the front and flanks.

7. Sufficient depth and good lateral communication in rear of the entrenchments, so as to allow the covered passage of troops to any desired point.

8. Good means of retreat; if possible several roads or tracks, and a strong rallying position in rear.

9. No good positions for the enemy's artillery.

10. Favourable ground, on which all arms can co-operate for the decisive counter-attack.

11. Water.

12. If the position is parallel to the enemy's line of advance (a flank position) the flank nearer the enemy should rest on an impassable obstacle; and a line of retreat should be selected which runs for some distance perpendicular to the front. (*Section* 125, *Combined Training*, 1905).

Trenches and guns on the sky line should always be avoided, as they form so good a target, especially if the enemy has good artillery.

Trenches may be constructed on the sky line and not occupied in order to deceive an enemy; under all other circumstances they should be concealed as much as possible.

The foregoing are some of the chief points to be considered in reconnoitring a position that is to be occupied for defence. There are, of course, others, which must not escape notice. Thus, villages, farm buildings, &c., occurring in the proposed line are of great importance. Slopes whose summits will be occupied by infantry, or guns, must be carefully noted. Gentle slopes are much more effectively defended by musketry fire than very steep ones. The ground at their foot, if uneven or broken, may favour the attack, by affording cover at a critical time. As regards Artillery, it must be remembered that its effective fire *commences* at about 2,000 yards for field guns and 2,500 yards for heavy guns, and extends about 1,500 yards beyond this. The extreme range is about 6,000 for field and 10,000 for heavy guns. Therefore *steep* ground immediately in front of the guns is advantageous, because there will probably be less loss from the enemy's shells (which may bury themselves instead of ricochetting), and because fire can be longer continued over the heads of their own infantry with the minimum of annoyance to them. Streams and woods play important parts on battle-fields, and their existence, direction, extent, &c., will of course be accurately delineated on the sketch, or drawn attention to in the report.

Always, whenever possible, look at your position from the direction of the enemy's probable advance, and note its weak points.

The nature of the soil as affecting entrenchments, and in certain cases the supply of civilian labour, tools and transport, are important items to note.

RECONNAISSANCE OF A ROAD

Generally the primary object of a road reconnaissance will be to facilitate an advance by collecting information as to its breadth, condition, gradients, &c., and the nature of the country traversed by it: but a secondary object of the reconnaissance may be to ascertain particulars about supplies and water procurable *en route*, or to find along it camping grounds, bivouacs, positions for advanced guards, &c. As stated before, it must depend upon the circumstances of the case, which of all the details claiming attention shall receive most notice from the reconnoitrer.

It is more convenient if the road in the sketch is kept up the centre of the paper (*See page* 81) and the sketch itself must include at least half a mile of country on each side of it. As a rule the reconnoitrer need not leave the road. Sometimes it may be necessary to do so to see where a cross road leads to, or to ascertain particulars about supplies, &c., from some village. The scale will usually be about 1″ or 2″ to a mile; therefore time must not be wasted in trying to show details too small to be adequately represented. In the margin, small freehand sketches may be made of any object which it may be useful to recognise at once, or important to identify. But such sketches should not be made simply to exhibit skill in drawing. The following, then, are points in the reconnaissance of a road, which, according to circumstances, must be more or less noticed.

The general direction of the road, N., N.E., &c.; its nature, whether metalled or not; width of metalling; state of repair, and whether materials for repair are available in the neighbourhood; its boundaries, *i.e.*, are there hedges, ditches, or fences, &c., along it, or can troops move freely on and off it without difficulty? Its gradients; any places where it widens, or crosses a common, &c., thus presenting facilities for troops to pass each other without confusion; landmarks such as churches, public houses, milestones, conspicuous trees, &c., which may guide the march of troops, and which are either on the road or off it; bridges passed over, their width and length, and whether of masonry, wood, or iron, and strong enough to bear guns, &c.,* places along the road for encampments, or the

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*Generally it would not be necessary to say more than this about a bridge in an ordinary road report. But if it is a case of blowing up a bridge, or defending its passage, then more information would be required, *e.g.*, breadth, length, and material of which built, the number and span of the arches, and their shape—whether segmental, elliptical, or semi-circular; the height of the roadway above the water; the thickness and nature of piers and abutments, &c.

A hand sketch with dimensions is the best method of showing his.

bivouac of troops, due regard being had to the easy supply of fuel, forage, and water (*See pages* 200–204); water supply along the route for men and horses; lateral communications with parallel roads; anything that might obstruct or delay progress, such as woods, defiles, embankments, sandy, muddy, broken or steep places, &c. Guns can be taken up slopes of 1 in 4 for short distances, and heavy service wagons would require extra horses for slopes steeper than 1 in 7. Finally, the character of the country on either side of the road must invariably be noticed. It must be of the utmost importance to know whether the soil is firm, and the country generally open, and traversable by the three arms; or whether it is close, wooded, the view limited, and movements or manœuvres over it in consequence difficult or impracticable.

RECONNAISSANCE OF A RIVER.

The reconnaissance of a river may be undertaken to find some way of crossing it, there being no existing bridges; or regarding it as an obstacle, to collect information upon which the best way of guarding and defending it may be determined. According to circumstances, therefore, the following points will receive the reconnoitrer's attention:—

General direction of the river, and character of the country through which it flows, whether open, wooded, marshy, &c.; width generally, and at particular points; depth, liability to floods; Is it navigable? To what extent? For what kind of boats? Rapidity of the current:—

1 mile an hour is considered "sluggish."
2 ,, ,, "swift."
3 ,, ,, "rapid."
4 ,, ,, "very rapid."
6 ,, ,, "a torrent."

Were any boats seen? What kind of boats? What carrying capacity? In what numbers could they be collected? Nature of the bed of the river.

Note 1.—To ascertain the rate of the current, throw a branch into the stream, and see how far it floats in (say) 1 minute. From this the number of miles per hour can be calculated. Or $\frac{7}{10}$ths of the No. of feet per second, will give the number of miles per hour.

Note 2.—Ice 3 inches thick will bear infantry and field artillery. Ice 6 to 8 inches thick will bear heavy guns, and baggage waggons, &c.

The existence of islands and tributary streams, must be noticed. They facilitate bridging, and help to conceal preparations; the relative command of the banks is a matter of great importance, and also the nature of the approaches to points recommended for passage.

Regarding the river as a defensive obstacle, the existing means of crossing it by bridges and fords must be carefully noted, and what points command them; also villages, woods, or other vantage points along the banks; and points at which inundations might be effected, &c., &c.

Note 3.—In describing a river, the terms north, or south bank, are apt to mislead, and should not be used. In a winding river, the same bank may sometimes be the north, and sometimes the south bank. Facing in the direction in which the current is flowing, the bank on the right hand is the right bank; and that on the left hand the left bank; and these terms only should be employed.

Fords may be found by dropping down a river in a boat with a sounding rod; or by noticing tracks leading to and from them; or by questioning villagers. A river is often fordable obliquely when it cannot be forded straight across. The depth of a ford should always be ascertained personally. Safe limits are 3 feet for infantry, 4 feet for cavalry, 2 feet 4 inches for guns. The nature of the bottom is of consequence. If it is sandy the depth will sensibly increase if the ford is much used. The sand gets stirred up and carried away by the current.

FERRIES, if seen, must be described, number of men carried at one trip, time occupied, &c.

RECONNAISSANCE OF A RAILROAD.

The following are some of the most important points to which attention should be directed :—

The line itself.—Number of lines and general state of repair. Its gauge in feet and inches (measured from inside to inside), nature of the country traversed by it, embankments and cuttings, their length, height, depth, &c. ; bridges and tunnels, materials for repair, ballast, rails, sleepers, spikes, fish plates, tools, &c., where located. The best places for rendering the railroad unserviceable—blowing in tunnels or removing rails. (In removing rail do so at a curve and take the outer one.)

Rolling Stock.—What engines and carriages are available ; what horse and cattle trucks, and goods waggons, &c. ; carrying capacity of each ; workshops and facilities for repairs.

The Stations : their size and construction ; roofed or not ; capabilities for defence ; length and breadth of platforms ; height above rails, and means of lengthening them ; facilities for entraining and detraining troops, horses, guns, &c. ; sidings and end loading docks ; approaches and entrances to the stations ; spaces outside for the assembly or bivouac of troops, the telegraphic arrangements ; water for engines and for drinking ; fuel for engines ; means for shunting—turn tables, cranes, &c.

Personnel.—What railway officials are available, drivers, stokers, pointsmen, gangers, signalmen, &c.

Telegraphs and Telephones.—Number of wires and apparatus.

" In drawing the plan of a Railway Station, to show its sidings, points, &c., in detail, it is usual to exaggerate the widths, or make the transverse scale three or four times larger than the longitudinal scale, *each pair* of rails being shown by a *single* thick line."

RECONNAISSANCE OF A VILLAGE.

The object of the reconnaissance may be the occupation of the village for defence, or simply to see what accommodation and supplies it can afford.

In the first case, it is necessary to bear in mind that its suitability for defence will depend upon the form and nature of the surrounding ground; and upon the shape of the village, and the nature and construction of its houses. These points, then, must receive the reconnoitrer's careful attention. Villages are generally more or less of one of the three following types:—

(*a*) Circular.

(*b*) Salient towards the enemy, *i.e.*, consisting chiefly of one long straggling street, end on towards the enemy.

(*c*) Broadside to the enemy.

Each type has some particular advantages and defects for the purpose of defence. Regarding the houses: Are they of one or more storeys? What are they built of? Are the roofs thatched, slate, or flat, &c.? Are there any particularly strong and spacious buildings, *e.g.*, a church, town hall, &c., which would be useful as a reduit, or hospital, &c.? Is the village within range of commanding ground? Is there a good view, and a clear field of fire, all round it? &c., &c. It should be noted if there are post and telegraph offices in the place; and the names and addresses of the officials in charge, and of the magistrate, or chief civil authority, should be ascertained and reported.

(Notes on accommodation and supplies will be found further on.)

RECONNAISSANCE OF A WOOD.

The shape and extent of a wood must be defined: the roads and paths leading through it must be shown, also any streams, &c., intersecting it, and any glades, clearings, &c., inside it. The nature, and size, of the timber must be noted, and whether any undergrowth exists or not. As a rule pine and beech woods are free from undergrowth. Also, whether there are any outlying clumps, their size and distance from the main wood. Landmarks, or anything that will serve to guide the march of troops, should be carefully pointed out; and finally, the reconnaissance should embrace the ground not only in front of the wood, and on its flanks. but also in its rear.

RECONNAISSANCE OF CAMPING-GROUNDS AND BIVOUACS.

The following are the camp and bivouac spaces as laid down in *Field Service Pocket Book, 1908*:—

Unit at War Establishment.	Camping and Bivouac Space in yards.	Remarks.
Army Head Quarters ...	100 by 150	
Divisional Head Quarters	50 ,, 100	
Brigade Head Quarters ...	30 ,, 50	
Cavalry Regiment ...	161 ,, 150	
Cavalry Squadron ...	55 ,, 150	
Battery or Amm. Column	75 ,, 150	
Divisional Amm. Column	300 ,, 150	
Field Troop ...	50 ,, 50	
Wireless Telegraph Coy....	35 ,, 100	
Divisional ,, ,, ...	35 ,, 50	
Cable ,, ,, ...	70 ,, 150	
Air Line ,, ,, ...	35 ,, 150	
Balloon Company ...	50 ,, 50	
Field Company ...	35 ,, 150	
Battalion M.I. ...	200 ,, 150	
Infantry Battalion ...	65 ,, 150	Cavalry, Mounted Infantry and Infantry, require an alarm post of 60 yds. depth, in front of the camp or bivouac, in addition to the depth shown below. Other arms fall in on the ground where they camp or bivouac.
Cav. Div. T. and S. Column	375 ,, 150	
Divisional T. and S. ,,	300 ,, 150	
Mtd. Bde. or Army Troops T. and S. Column ...	75 ,, 150	
Divisional T. and S. Park	450 ,, 150	
Field Ambulance ...	120 ,, 200	
Cavalry Field Ambulance	80 ,, 180	
An Inf. Bde. in one line ...	280 ,, 150	
A Cavalry Bde. in one line	515 ,, 150	
General Hospital ...	400 ,, 250	
Horses ... require each	6ft. ,, 18ft.	
Mules, ponies, bullocks ,,	4ft. ,, 15ft.	
Camels ,,	6ft. ,, 15ft.	
Elephants ,,	9ft. ,, 21ft.	

At a pinch, less space would do; but as a rule, crowding must be avoided, and the more room allowed the better.

The selection of a site for an encampment is governed by

(*a*) Military considerations.

(*b*) Sanitary considerations.

For temporary occupation, and with the enemy in the vicinity, the former entirely out-weigh the latter; while if the camp is to be occupied for a long time, or if the enemy is at a distance, sanitary considerations are all important. According to circumstances, then, the reconnoitrer will bear the following points in mind, and notice them more or less prominently in his report.

Sufficient space for the force to be encamped: tactical advantages: as afforded positively, by the occupation of high ground, with a clear view, &c., and negatively, by the locality not being commanded by any spot within range, &c.: site for the encampment of each arm to be favourable as regards slopes, &c., to the movement and action of that arm: easy approaches, and good communications: convenience as regards supplies, fuel, water, &c.

Sanitary considerations: drainage and soil: newly ploughed land, and the sites of old encampments should be avoided: sites on sand and gravel are good, clay is usually damp: the proximity of marshes is dangerous, and to encamp in a forest at certain seasons is deadly. "A Division of the French Army which encamped in a forest the night before the battle of Raab was almost decimated by fever."

RECONNAISSANCE OF A MOUNTAIN RANGE.

In reconnoitring a range of mountains, or hills, the chief points to observe would be the roads leading through and over them, and their practicability for the different arms. Their width and gradients would be specially noted, and the possibility of improving them remarked on. Besides the main roads, every mountain path, however difficult, should be examined, and reported upon. The routes leading over the regular passes would be almost certainly held by the enemy (if they led into an enemy's country), and to attack their positions in front, using these roads, would probably not be feasible. Any means, therefore, by which turning, or flanking movements can be made, become of the greatest value.* If any defiles or passes exist, they should be examined with great care, and the following points particularly noted :—

Track or roadway; gradients; any other tracks leading into the main one; length and breadth, and open places; ground on flanks, and if it can be turned; exit, whether commanded by artillery or rifle fire; position for local defence and for artillery, &c. Points from which good views can be obtained should be marked. *Freehand landscape sketching may be of very great value in this kind of reconnaissance.*

ACCOMMODATION AND SUPPLIES.

There are various ways of estimating the accommodation available in a village for men and horses. If the inhabitants are friendly, the magistrate, postmaster, or other official, would probably be able to give the best information regarding this and other matters. If they cannot be relied on, then one method is to estimate the population (which may be done *roughly* by allowing 5 inhabitants to each small house in the place, and 10 to each large one) and allow from 2 to 5 soldiers per inhabitant, according to the class of village or town. For a one night's halt, a rough estimate of accommodation can be made as follows :—

For each room 15 feet wide, or less, allow 1 man per yard of length.

For each room between 15 feet and 25 feet wide, allow 2 men per yard of length.

For each room over 25 feet wide, allow 3 men per yard of length.

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* For instance, *vide* the operations which led to the evacuation of the Fort of Ali Musjid, at the entrance of the Khyber Pass in November, 1878. The track followed by the British turning force was a mere goat path, "most trying, difficult, and fatiguing;" but the object was gained, for the Afghans, who the day before had successfully resisted a frontal attack, retreated directly their rear was threatened.

"Where two men can place their feet an Army can pass."—*Napoleon.* And again—"Annibal a forcé les Alpes, Nous—nous les avons tournées."

A certain amount of space must be left for the inhabitants.

A third method, suggested by the late Sir George Colley, was to measure the front of the houses; and for those one room deep, to allow one man per yard of front; for those two rooms deep, two men per yard of front; and multiply (in both cases) by the number of storeys. Shelter for horses may be allotted in barns and outhouses at the rate of 5 feet of length per horse. Buildings or sheds 24 feet wide will accommodate two rows of horses, and leave a passage between.

In reporting on accommodation and supplies, comparative terms like "large," "small," "ample," &c., should be avoided. What to one man appears large, or ample, may by another be considered small or insufficient. Therefore, specific terms only should be employed. The most important supplies to gather information about are water, fuel, forage, (hay, straw, and grain) and meat (as represented by cattle and sheep). The water supply should always be carefully described, special notice being taken of the facilities for watering horses. The names and addresses of butchers and bakers should be given, and the position of forges and smiths' shops noted. The description and amount of carriage that the place can supply should be reported. Also the numbers of bicycles, motors, traction engines and trucks; motor and bicycle repair shops, petrol, etc., etc.

Water.—Where does it come from? Is quality good? Is the supply limited? Good water should be colourless and transparent, free from taste or smell, and deposit no sediment. An average daily allowance for all purposes is 5 gallons per man and 10 gallons per horse when in standing camp. At other times 1 gallon is sufficient for a man for cooking and drinking, and 2 to 3 gallons for washing. One cubic foot of water = 6·23 (say $6\frac{1}{4}$) gallons; and one gallon weighs 10 lbs.

To calculate the supply available from a running stream, use either of these two formulæ, in both of which B = average breadth of stream *in feet*, D = average depth *in feet*, and V = velocity *in feet per minute*:—

(1) B × D × V × 1,800 = No. of men for whom there is 24 hours' supply at 5 gallons a man.

(2) B × D × V × 6·23 × 60 × 24 = B × D × V × 9,000 = No. of gallons obtainable in 24 hours. And, of course, the No. of gallons multiplied by 5 will give the No. of men for whom there is a 24 hours' supply of water.

Example.—A stream is 2 feet wide, 6 inches deep, and has a velocity of 50 feet per minute. How many men will it supply with water in a day?

2 × $\frac{1}{2}$ × 50 × 1,800 = 90,000 men at 5 gallons a day each.—*Answer.*

To calculate the supply obtainable from a well :—

Area (in feet) × depth (in feet) × 6·23 = actual No. of gallons in well. But as water is taken out of a well, more will run in, therefore, to ascertain how much water a well will supply in a given time, bale out water till the level is sensibly reduced ; then note how long it takes to rise to its original level; and then the area of the well being ascertained, the amount of water coming into the well in any given period can be calculated.

For example, the area of a well is 30 square feet. You bale from it till you have reduced the level 1 foot. You then discontinue baling, and find in 2 hours the water has risen to its original level. What is the supply in gallons per hour that can be reckoned upon?

As the area is 30 square feet, and the water rises 1 foot in 2 hours, the amount coming into the well is evidently 30 cubic feet in 2 hours, or 15 cubic feet in one hour, or 15 × 6.23 = 93.45 gallons per hour.

Again, suppose you have no time to wait till the well refills, but you note that after half an hour's baling at the rate of 1 cubic foot per minute, that the level is reduced by 6 inches. In this case, what would be the supply per hour?

Here, the amount baled out is 30 cubic feet; but, the area being 30 square feet, and the level being reduced by the operation only 6 inches, only 15 cubic feet (30 × $\frac{1}{2}$) are accounted for, therefore the balance of 15 cubic feet is the amount that must have come into the well in half-an hour while you were baling. Therefore the supply is 30 cubic feet per hour, or 186·9 gallons.

Forage and Fodder.—

1 cubic yard of straw weighs about 140 lbs. in the rick.
,, ,, hay ,, 200 lbs. ,,
,, ,, grain weighs about 900 to 1300 lbs. (roughly 20 bushels).
(Oats are the lightest).

A bushel of wheat weighs 70 lbs.
,, barley ,, 60 lbs.
,, oats ,, 45 lbs.

1 acre of grass will give from 1 to 3 tons of hay.
,, wheat ,, ,, 30 to 40 bushels.
,, barley ,, ,, 40 to 50 bushels.
,, oats ,, ,, 50 to 60 bushels.

Note.—An acre is 4840 square yards, or a field about 70 yards square. A bushel varies from 40 to 60 lbs.

To estimate the quantity of hay, or straw, in a rick:— Multiply the cubical contents (in yards) of the rick by 200 to get the weight, *in pounds*, of hay: or by 140 for straw.

Or, use the following formulæ, in which H is the height to the eaves + half the height from eaves to top, B its breadth, and L its length: the rick being rectangular in shape, with a gable roof.

$$\frac{H \times B \times L}{12} = \text{No. of tons of hay in the rick.}$$

$$\frac{H \times B \times L}{17} = \text{No. of tons of straw in the rick.}$$

If the rick is a circular one, its cubical contents will be $\pi r^2 \times H$, and this divided by 12, or 17, as the case may be, will give the answer in tons. The value of π may be taken as $3\frac{1}{7}$, and r is of course the radius of the stack.

Examples. 1.—The dimensions of a haystack are 7 yards wide, 11 yards long, 3 yards high from ground to eaves, and 2 yards from eaves to apex. Where are its contents?

$$\frac{7 \times 11 \times 4}{12} = 25\tfrac{2}{3} \text{ tons.} \quad \textit{Answer.}$$

2. The diameter of a circular stack of straw is 8 yards. Its height from ground to eaves is 8ft., and from eaves to apex 8 ft. What are its contents?

Radius is 4 yards, and height is 8ft. + 4ft. = 12ft. = 4yds. therefore No. of tons in stack $= \frac{3\frac{1}{7} \times 4^2 \times 4}{17} = \frac{22 \times 16 \times 4}{7 \times 17}$

$= 11\frac{5}{6}$ tons approx. *Answer.*

QUESTIONS FOR PRACTICE.

1.—A stream 5ft. wide, 4 inches deep, flows at the rate of 3 miles an hour. How many men would it supply in 24 hours?

2.—Give the breadth, depth, and rate of flow, of a stream that would supply sufficient water for 250,000 men.

3.—An officer is directed to report on the water supply derivable from 6 wells at a camping-ground on a desert route. He bales out water from one, at the rate of 2 cubic feet per minute, and in half an hour finds that the level of the water has perceptibly fallen. The baling is then discontinued, and by the end of the following hour the water has risen again exactly to its former level. What supply in gallons would the officer report as available per hour from the 6 wells, supposing them all to yield the same quantity?

4.—Had the area of the interior of each of the wells in the foregoing question been 15 superficial feet, and had the water in the one experimented upon fallen 12 inches after the half hours' baling, at the rate of 2 cubit feet per minute, what supply in gallons, per hour, would the officer have reported as available from the 6 wells, supposing him to have had no time to wait until the well refilled?

5.—Give the contents in tons of a stack of hay which is 7 yards long, 4 yards broad, and 8 feet to the eaves, and 14 feet from the eaves to the ridge.

6.—What are the contents, in tons, of a circular rick of straw : diameter, 10 yards; height, 12 ft. to eaves, 9 ft. to apex.

COAST RECONNAISSANCE.

This work would generally be carried out by the Navy, but one might find oneself detailed to do it.

Such a reconnaissance would probably have for its object the opposing of an enemy's landing, or the embarkation or disembarkation of our own troops.

The following points should be noted:—Anchorage, whether open or sheltered; tides and currents; whether there are any facilities for landing troops and stores; nature of shore, rock, sand, &c.; any points where landing piers could be constructed; any defensive works commanding the landing places, or position for covering parties.

RECONNAISSANCE OF A POSITION FOR DEFENCE.

Combined Training, 1905, para. 124, gives the chief points to be noted in reconnoitring a position for defence, and in para. 125 the chief requisites of such a position are stated.

In selecting the line of defence, an inspection of the ground is most important. A sketch, useful as it may be in organising the defence, should in no case interfere with this inspection. No sketch, however accurate, can say how far crops, bushes, trees, etc., etc., interfere with the view.

RECONNAISSANCE OF A POSITION HELD BY THE ENEMY.

A reconnaissance of this sort will probably mean an officer getting as near as he can to the position, and with the aid of a plane table or prismatic compass and range finder making as accurate a sketch as time and means admit. Some useful work was done in this way at the River Tugela in the late Boer War.

Any gun positions or trenches, camps, etc., noticed should be shown.

A report, with a freehand panorama sketch, should be made. The extent of the position and what appears to be the strongest and weakest points, and best lines for attack, etc., etc., should be noted.

RECONNAISSANCE OF AN OUTPOST POSITION.

Should a good map be obtainable, an approximate line for the outposts may be chosen, but the actual ground should not be fixed till a reconnaissance has been made, and the details, *i.e.*, the position of sentries, picquets, supports, etc., should never be settled on the map, but only after a personal inspection of the ground has been made.

The following few points about an outpost position should be noted :—

i. It should be strong for defence.

ii. Difficult to surprise.

iii. Easy to retire from.

iv. Commanding ground which allows a large extent of ground to be kept under observation is an advantage, but if the ground to the front is well patrolled, facilities for protracted resistance are more important than facilities for observation.

v. The advanced troops, when placed along well-defined natural features, such as streams, ridges, outer edges of woods, sunken roads, etc., facilitate command, co-operation, and inter-communication, but it must be borne in mind that the best tactical dispositions are the first consideration.

vi. In civilised war night outposts are not generally drawn in closer to the main body, except for some adequate tactical reason, *i.e.*, to hold the junction of roads or paths, etc. (Combined Training, 1905, p. 68).

All officers on outpost duty in command of any formed body of men, *i.e.*, picquets, detached posts, supports, etc., should as soon as possible have sketches made of their respective commands. The sketch might be on a scale of 3 or 4 inches to 1 mile. All ground in the immediate vicinity, 400 to 600 yards radius, should be included. The exact position of sentry posts, picquets, supports, by day and night, etc., etc., direction patrols take and distance they go, direction and distance to picquets on right and left, and to any troops in front or rear. The ranges to conspicuous objects, woods, villages, farms, or any commanding ground should be ascertained and noted. The best line of retreat.

TO MAKE USE OF A MAP IN THE FIELD.

It has already been remarked that every officer proceeding on service should be provided with a map of the scene of operations. With this map, and a compass, he should have no difficulty in finding his way about in a strange country. The correctness of the map may be tested by drawing a line across it at random, and following that line, to see if it really crosses those lines and features which it cuts on the map, or crosses others which are not shown. Another test is to measure the distance on the map between two points which can be identified on the ground—two villages for instance—and then compare this measurement with the actual distance apart of those points. A few tests of this kind will soon show whether the map is up to date, and reliable, or not.

To use the map in the field, treat it as if it was a sketch on a plane table; that is, before trying to identify distant points by means of the map, spread it out on the ground, and "set" it by the aid of the compass; remembering, however, that the top of the map is true, or geographical north, and that the variation of the compass must be allowed for. As soon as the map is "set," then you can pivot a pencil, or pointer of some sort, on the spot at which you are standing, and observing the direction of various distant objects, identify them by reference to the map, and examine them at leisure. If you cannot mark on the map the spot at which you are standing, then having "set" the map, you must look out for a couple of objects which *can* be identified on the map, and use them to resect your position, exactly as if you were plane-tabling. If you have no compass by which to "set" the map, you must find your place "by adjustment," as described on page 107.

GENERAL REPORT.

2 (*continued on following page.*)

I The Road.		
II. Bridges.		
III. Rate of Marching.		
IV. Towns and Villages.		
V. Water.		
VI. The Country.		
VII. Rivers.		
VIII. Halting Places.		
IX. Camping Grounds.		
X. Positions.		
XI. Lateral Communications		
XII. Railways.		
XIII.		***Signature.*** ***Date.***

(continued).

Information as to Routes, to be given under the various headings.

I. The Roadway, metalled or not, width of metalled portion; present condition; whether level or hilly, the steepest gradients to be stated in the latter case. Details as to any part that constitutes a defile, such as hollow ways or village streets. Nature of the fences by which bounded.

II. Bridges. Full details; fords near the bridges.

III. Anything that might tend to retard the usual rate of marching.

IV. Towns and Villages. Material of the houses inflammable or otherwise. Defensibility. Buildings suitable for barracks, stores, magazines, hospitals; available entrenching tools. Roughly numbers which can be billeted. (Statistics, if required, are to be given in a separate form).

V. Water to be found near the road fit for drinking or for watering horses, giving numbers able to water at one time, and nature of approaches.

VI. Character of cultivation; nature of the fences. View, whether much restricted by wood, &c. Possibility of movement across country, or parallel to the road. Surface of the ground.

VII. Rivers; depth, width, rapidity, nature of banks and bottom; passages; command of one bank over the other.

VIII. Halting places and shunting places where part of the column could pass from rear to front, giving rough dimensions.

IX. Camping or bivouac ground, force for which suitable (when such information is required).

X. Positions (according to the instructions) favourable to the enemy; points whence the road can be observed.

XI. Roads or tracks crossing or joining the road; construction, width condition.

XII. Railways, gauge, single or double. Stores and rolling stock, if such information is required.

XIII. Any other information likely to be useful.

ROAD REPORT.

From

To

Executed by

Date

CHAPTER XIV.

THE "FIELD SKETCHING" BOARD*: HOW TO USE IT.

By Major H. A. Sawyer, B.S.C.,
Assistant Quartermaster-General, Intelligence Branch.

Description and Make.—A former pattern was as follows (see diagram): To ¼-inch light wooden board (*B*), seven inches long (measured with the grain) and six inches wide, are fastened at one end a thick strip of gun metal (*M*), and to the other a thinner piece of copper (*C*), each protruding at either end an inch beyond the board. Near each end are bulged holes as sockets to take the ends of "rollers" (*R*). The copper strip being thin and elastic permits of the rollers being pushed into their proper places, and taken out at will by merely pressing the copper ends outwards.

The friction between these bulged holes or sockets, and the ends of the rollers, prevent these from unrolling of their own accord.

As a protection to the copper strip, and as a socket for the needle compass (*N*), is further attached a wooden piece (*W*). These three pieces, *M*, *C*, and *W*, are bolted together by bolts that run through the board (*B*) (shown in dotted lines). In the centre of the board at the back is a leather strap which can revolve round a flat copper nail head. The sketching board weighs one pound. It is strongly built, and can stand a good deal of knocking about.

Recently a lighter kind has been made with no metal about it except the spring copper strip. The compass is smaller, and the whole affair less than half a pound in weight. It is quite strong enough, and the difference in weight is of much more importance than generally supposed. I would strongly recommend the more modern and lighter kind for ordinary use; moreover, it is half the price of the former.

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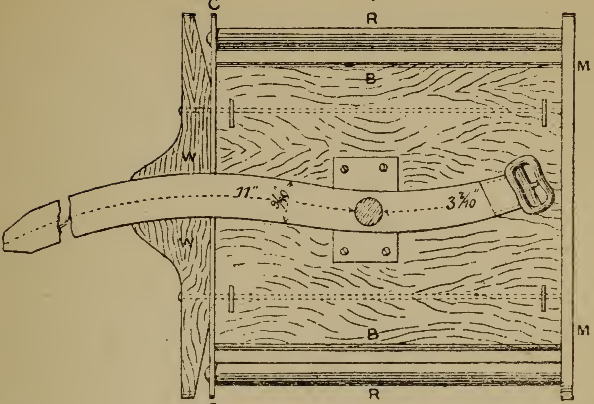
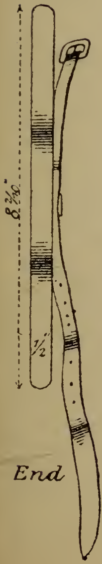
* Known also as the "Cavalry Sketching Case."

Plate XXXV.

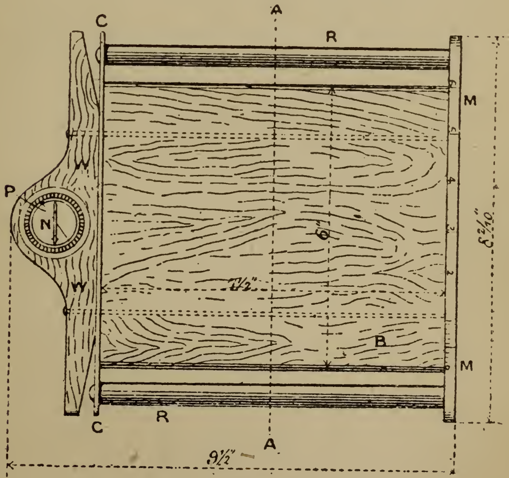
Scale 1/4th full size.



Back



End



Front

Note.—Since this chapter was first written, several patterns have been introduced with many improvements. Most of them have hollow metal rollers with a slit in them, instead of wooden ones. In one pattern the rollers can be clamped, keeping the paper flat and taut, while in another there is a very useful clinometer attached to the back. The principle of working, however, remains the same, which is the main consideration.

To each case is generally added a flat ruler, 10″ long, 1″ wide, as also two broad India-rubber bands.

The compass is fixed and lies flush with the surface of the board. It has a glass cover that can be made to revolve horizontally by pushing a small metal point (*P*), from which point is struck a clearly-marked diameter cut in the glass. Thus *P*, and the glass, and the diameter revolve together. This diameter I shall call the "glass meridian." As the case is generally held in such a manner that the compass is to the left, I shall further call *R* the upper roller and *R* the lower roller. The imaginary line passing through the centre of the two rollers I shall also call the ‘axis" (*A A*).

To prepare it for use.—Drawing paper must be cut into strips just a little less wide than the clear length of the rollers. These are generally split in two pieces, the angle of the cross section of one being about 270° and of the other 90°. One end of the strip of paper must now be turned down about half an inch on to that side of the paper on which it is intended to draw; place the smaller piece of the roller into this "turn down," and place these, *viz.*, paper and the small piece of the roller, into the bigger piece. Hold all this tight together, place the back of the paper on to the board, and then the roller into its inelastic socket; lastly, the other end into the copper spring socket. Take a sharp knife and cut off any pieces of paper where they protrude from the roller's slit. Now roll up tight the whole strip of paper. The paper must move from the upper surface of the board to underneath the roller; this protects the drawing from being smudged. An elastic band placed over the paper and board at *D* will prevent the paper from unrolling. Treat the other end of the paper in the same way. Give it two or three turns, and affix the other rubber band at *E*. The bulk of the paper must be on the "upper" roller to start with. The board is now ready to be "set."

How to "set."—"Setting" the board is merely for the purpose of keeping the work as much as possible in the centre of the paper (*viz.*, near the axis). This is made much of by instructors, and is a source of anxiety to the beginner. At an examination I have seen an unfortunate rub out 3 miles of work and ride back to start afresh because he ran off the paper. As will be shown later on, a bad "set" can be remedied without rubbing out a stroke. It looks well no doubt to have a 9-mile sketch on 6″ to a mile in the centre of a strip of paper; it is perhaps a sign of a good set (if the road is not very tortuous), but it is of little moment in practice. To lay stress on it is mere pedantry.

(*a*) *To "set" without a map.*—If standing on an elevation, and you can see for some way the general alignment which the work (a road) will take, place the "axis" in the alignment (compass to the left), and when the needle is steady, slightly tilt the board (to fix the needle); then by turning the point *P*, make the "glass meridian" coincide with the needle. On a scale of one mile to an inch, such a "glass meridian" will hold good for any turns of the road reaching 3 miles to the right, and 3 miles to the left of its general direction.

(*b*) *To "set" with a map.*—If a small scale map is given, and on it are given two points, say *X* and *Y*, ten miles apart, the road joining which is to be sketched, place the board with its "axis" on the alignment *X Y* on the map. On the map draw a magnetic meridian, allowing for the correct variation for the year and place. Now make your glass meridian coincide (parallel) with this magnetic meridian, and the board is "set."

What material to use. — Any smooth-surfaced tough paper is the best. It takes less dirt, smudges less, and is best for after treatment. Cartridge paper is excellent. Its yellowish surface is not so trying to the eyes as pure white paper. For much out-door work I always prepare my " rolls " (strips cut to the width of my board, kept rolled up ready for use) by dipping them in a light solution of indigo. Bankpost rolls should always be at hand. They are most useful when only ferrotype reproduction can be counted on. When using bankpost paper, cover the surface of the board (underneath the roll) with a piece of white paper. Never use ruled paper. In theory it is splendid, in practice for this work an abomination ; pencil, pen and ink, are the only legitimate materials for drawing with for military purposes in the field. Rubber elastic bands, broad and large, should be kept in stock (on person) ; on the edges of the ruler you can have scales of walks, trots, canters, time, yards. The ruler is sometimes convenient, but more often not. I have discarded it altogether for a piece of cardboard, about 2 inches long, one inch wide, properly scaled and varnished over. Tied by a strong thread (half a yard long) to the right-hand upper corner of the board, when not in use shoved under the top elastic band, it can never be lost, and is always handy. Practice soon allows of the longest " shoots " being made perfectly straight freehand.

Robertson's Liquid Indian Ink is first class. I have a little left in a bottle I first opened in 1883. It is still in perfect order. An ordinary fine-pointed steel pen is best of all.

How to carry it.—When at work the board is meant to be strapped round the wrist or forearm, but my advice is try first any other way but that, for it is a most uncomfortable, trying, and unsteady method. I always hold mine between thumb and forefinger of left hand, but keep the strap (unbuckled) firmly in the hand at the same time to steady it. When not at work the board should have a leather case and strap to pass over the shoulder, but the strap should be then shortened so as to bring the case close under the armpit. Some strap the board when done with round the upper arm, but I prefer a haversack to anything else. Mine holds board, pencils, ink, pens, rubber bands, foolscap (2 quires), rolls, sufficient for 1,000 miles of road (on one inch).

Measurement used.

(*a*) *Linear.*—Counting the horse's paces, or taking his rate of progress by time, are the only methods used for measuring distances when using this sketching board. The most accurate of these is, of course, counting the horse's "walk." Which to use, is regulated by the rule "Be as accurate as time permits." If you are marching with troops, for instance, by ordinary marches, you know you have 6 or 7 hours to do the 10 or 12 miles in. Make "walks" your scale for the forward alignment, trots and canters for offsets. Always have an orderly (mounted if possible) on the spot you set off from. Some allow the counting to be done by others. This, however, always turns out unsatisfactory. Counting a horse's "walks" is as accurate as pacing on foot if proper allowances are made. Every horse has his own "allowance." For an English horse I had I was obliged to allow (possibly owing to this country), even when in good condition at a "walk" one per cent. per hour, that is, after five hours on the road he stepped five per cent. short; with quick "walk and trot" work double that amount. A Yarkandi pony I have requires no allowance, even after carrying me the whole day. Allowances must also be made for the nature of the soil, slope or track, &c. In pebbly river bed (like North-western Frontier) horses walk tenderly and short; ditto on sloping ground. Some horses step out ten per cent at once when joined by another horse on the road, and lag again when alone With rifle ranges, mile stones, railway and telegraph lines, near every cantonment, there is no excuse for an officer not knowing his horse's paces and "allowances" at all times of the year. Hurried "gallops over" can, of course, only be done by time. It is not generally credited how accurate this too can be made. In "general reconnaissances" extending over many hundreds of miles, even when the dead reckoning is unchecked by astronomical observation, the error need be only very small.

In such a recent tour the dead reckoning (unchecked) of an Intelligence Branch Officer's (Bell) work, was found to be only 10 miles out, after a run of 600 miles.

"The Manual of Field Sketching and Reconnaissance" discourages the system of counting the horse's paces, and encourages the method of measuring distances by time. It is an excellent way of making a sketch, and should be the aim of all those who sketch on horseback, but it is a high state of perfection. The beginner is advised, therefore, to start sketching counting the horse's paces, and gradually to work himself up to the more difficult task in sketching of using "time" measurements.

The Germans in their regulations lay very little stress on accuracy, and the latest on the subject only require a freehand sketch (plan) not drawn to scale.

Our conditions, however, are different, for wherever the German fights, he nearly always does so with a perfect ordnance map of the theatre of war in his hand. We work generally in the wildest and most desolate parts of the world, hence the requirements in our army that every officer should be able to do something in the field sketching line.

Between the accurate "walk" sketch, and the freehand sketch plan of the reconnoitring officer, made at a gallop pursued by enemy's scouts, there are many phases of accuracy. The phase to go in for must be left to the gumption of the individual, but always enter on your sketch the reliance that should be placed on the measurements given.

This is most important because, if a good draftsman and you submit a pretty sketch, you will *primâ facie* carry more weight than a less talented draftsman, who, having had more leisure, had the means of making really more accurate measurements, lineal and angular.

It is wonderful how "eye wash" goes down with the uninitiated.

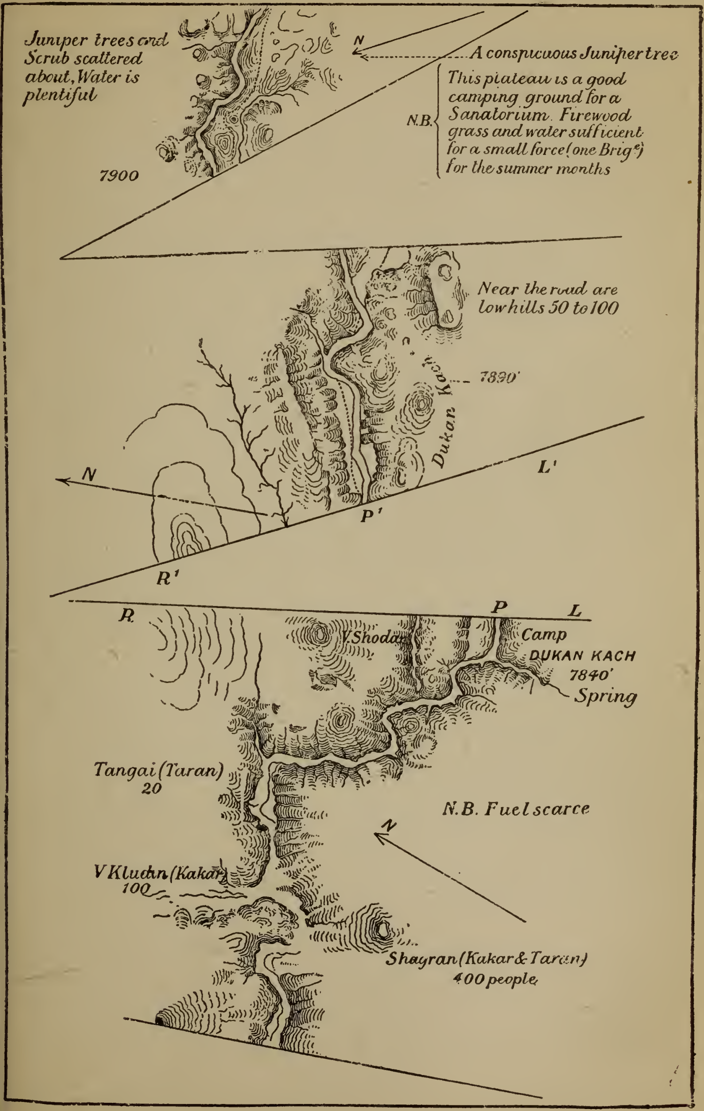
(*b*) *Measurements, Angular.*—The beginner is taught to lay the ruler on the new alignment; keeping his eye on the needle and "glass meridians" to see that these coincide; then to draw his pencil along the ruler. A little practice will show him that he can dispense with the ruler, and then he can draw a straight line towards the distant object freehand.

A very fair triangulation can also be made with the sketching board, quite as accurate as any work with a prismatic compass. Try it two or three times on foot, making a circuit from ¼-mile to six miles or more, and after a while you will find that you will close on your starting point in a remarkable manner.

Work in general, Style, &c.—Complete your sketch as you go along in pencil; do not trust to filling in details afterwards. Make full notes on margins in a neat and finished style. Be sparing of your India-rubber. The sketch should show everything of military value, and omit everything of no military value. At any time in one's work one may meet with an accident. The sketch should therefore at all times be in such a guise, that it can be taken up and finished by another at a moment's notice.

Hills should always be shown by approximate contours or form lines, and should be drawn in on the spot. On very small scale maps the form lines may be drawn so close to one another that it becomes horizontal hachuring. A specimen of a half-inch scale sketch is given on *Plate XXXVI.*

As already remarked, beginners show much anxiety about a good "set," and about keeping the sketch in the centre of the paper. For an "eye wash" sketch I admit it pays better, but for practical work, I think that to hug one side of the paper without detriment to all the ground one is able to bring in, has the advantage of giving more room for written remarks, or making freehand illustrations. Drawings made without this "field board" are often most inconveniently large sheets of paper, with additional pieces gummed on wherever the road "runs off" the last piece. Such work is a nuisance to everybody, besides being impracticable in the field. The field board saves us from all


Juniper trees and Scrub scattered about, Water is plentiful
N
A conspicuous Juniper tree
N.B. This plateau is a good camping ground for a Sanatorium. Firewood grass and water sufficient for a small force (one Brig^e) for the summer months
7900
Near the road are low hills 50 to 100
7830'
Dukan Kach
N
L'
P'
R'
R
P
L
V Shoda
Camp
DUKAN KACH
7840'
Spring
Tangai (Taran)
20
N.B. Fuel scarce
N
V Kluchn (Kakar)
100
Shayran (Kakar & Taran)
400 people

this, and any road, however tortuous, however long, can be brought on a strip from two inches to six inches wide, according to the scale used.

Whenever the drawing approaches the margin of the paper so close that you are not able to show all you want to, merely draw a line (*L R* in *Plate XXXVI.*) at right angles to the alignment on which you are at the moment standing, and draw in every detail nearly up to that line on both sides of the road. Then from that point (*P*) "re-set" your board for the same, or a new alignment, bringing it (that point P) as a fresh starting point into the centre of the board, as if starting *ab ovo*. Through this new point (*L*) draw another line (*R L*) at right angles to the new alignment. These will be "joining lines." Whenever a new "set" is made, don't forget to enter close to these joining lines the "old" and the "new" north points." The angle formed between these two "north points" and the "joining lines" must be the same. When it is required to show the road unbroken, the blank spaces between the "joining lines" have only to be cut out, and it will be found that the "north points" will be parallel.

Should the re-set have to be made where the ground is intricate, (and this is, of course, often the case) it may be convenient to put in the ground, in duplicate, beyond each joining line. In this way, by continually resetting, a sketch can be continued *ad infinitum* without inconvenience on a very narrow strip of paper, which is handy and compact.

To finish.—When at leisure, every evening, if the work extends over several days, I at once ink over the pencil drawing and marginal notes of that day. Anybody can do that for one if the above rule for *finishing* in pencil as one goes along is carried out; still it is more satisfactory to "ink over" oneself and at once. An hour suffices for the heaviest day's field work.

Before inking in, roll all the papers on to the upper roller, leaving the commencement of the pencil work in centre of board. Now begin to ink in. Go carefully over every pencil stroke, and resist imagination. If it makes it clearer, add to the remarks in the margin. Every six inches or so, draw (freehand) a line showing divisions of 100 yards, or 1,000 yards; miles or their approximations should always be entered on the road itself. As often as possible, put in the aneroid altitudes. When working mounted it is almost impossible to work with a clinometer, and an aneroid barometer becomes a necessity. On every elevation, give an estimate of its height over the road track where nearest to it. Make symbolic distinctions between your *estimates and aneriod readings*; never omit the "glass meridians or north points" near every "joining line." Enter your name in full, and state the time you had at your disposal, or at the rate at which you worked, and on mature reflection, your opinion of the value of your measurements: for you might have had a strange horse, or a bad compass, or a worthless aneroid, or what is far worse, you might have been "put out" before, or during the work.

Conclusion.—The sketch is now ready for submission. The principal use of a sketch, executed as above, is to serve as a diagram to illustrate a road report. The report should be written at the bottom of the sketch: it is the essential part of the work, and the sketcher as he works along should make constant notes. When mounted, it is of great advantage to be practised in the method of measuring distances by time.

With a little practice, the "Field Sketching Board" can be a handy and valuable instrument in most officers' hands. It is now cheap, and can be obtained in India, or made up in any regimental workshop. It can, moreover, be improvised without difficulty. An ordinary one-inch compass, which can be bought for a rupee, fixed firmly into the side of a thick piece of mill-board, 8″ × 10″, with two elastic bands, will answer almost as well. A bazaar workman can easily put in a revolving "glass meridian." Wilkinson's patent (price about 10 shillings), is a capital little compass; it is made for this very purpose; of being easily fastened to a thin wooden board or mill-board.

The principles of surveying taught at our schools of instruction, are equally applicable to reconnoitring with the field sketching board, so nothing need be said about it here. All I would point out is that, though with the above hints and his previous garrison course training, any fair draftsman can learn how to use it by himself, some practice will be required before he can work rapidly. It is hard bodily work, and has the advantage over some other bodily exercises of being intelligent work as well.

CHAPTER XV.

MILITARY FREEHAND SKETCHING.

By MAJOR R. F. PEARSON, "THE BUFFS."

Late Company Commander, Royal Military Academy.

Most officers never try freehand sketching because they say they "can't." Let me remind you, what no doubt you have often been told in your young days, there is no such word as "can't" in the dictionary, and it certainly applies in this case.

If you carefully follow these few notes, everyone should be able to do quite useful work. Let me add one word of encouragement to those who are not very good with their pencil: it is this—"However crooked your houses and woolly your trees may look from the artistic point of view, still if the detail (houses, woods, banks, streams, &c.), is accurately shown, your work will be useful, and in some cases may be of the greatest value.

Examples of the value of freehand sketches are to be found in the Afghan War (1879-80), the Chitral Campaign (1895), and the South African War (1899-1902).

I will first explain how to draw a panorama and then a hand or thumb-nail sketch.

Having decided the bit of country you wish to sketch, take your paper, and holding it at arm's length see how much of the country it covers. This shows you how much can be sketched. Supposing all the ground you wish to sketch does not come in on the one piece of paper, divide it into sections, and if necessary use two or more pieces ; they can be pasted together afterwards. Now look about for some horizontal line to draw first, such as a road, hedge, railway, ridge, &c. Next, with your pencil held vertically and at arm's length, measure the vertical distance from the above selected line to the top of the sketch and to the bottom.

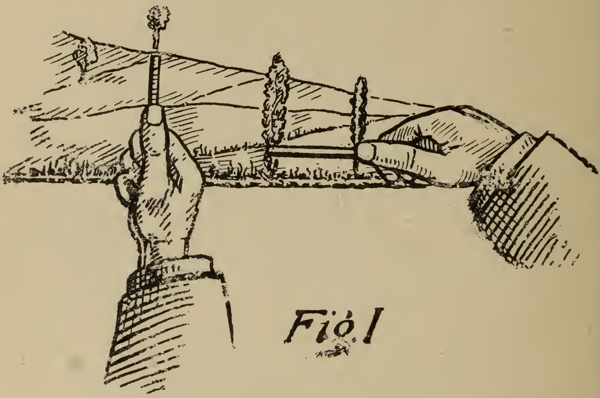


Fig. I

Fig. 1 shows how the pencil is held in taking measurements. Make the end of the pencil coincide with one object and move the thumb along until the end of it coincides with the other. The distance from your thumb to the end of the pencil is the actual measurement to be shown on the paper.

Having decided your starting line as before mentioned, draw it in, taking care to leave sufficient room above for head notes, and a small space below.

Noting some object on this initial line, draw it in on your sketch, and from it take horizontal measurements to objects on the right and left. Having got sufficient marked, take vertical measurements to any objects above and below, and then fill in the detail. You will find that at first you may require to make a lot of measurements, but as you become more adept the eye will become so trained that very few are needed.

The sketch finished, write above any notes which may be useful, such as names of places and ranges, *i.e.*, Beacon Hill, 4,800 yds. It should always be stated how the ranges were obtained—"Ranges from ½-inch map," or "Ranges taken with mekometer," &c. Underneath make a note or a small hand sketch from the map, stating the exact spot from where the view was taken.

To make this still more clear, we will now take a panorama and go through it in detail (see *Fig.* 2., Plate XXXVII.)

The railway is a good level line to take for the starting one. Draw it on your paper, then take measurement to top and bottom of sketch, and see you leave sufficient room for notes above and below.

Now decide on some point to take your horizontal measurements from; the nearest poplar in the line of those trees beyond the railway is a good point. Mark it on the line and take measurements to the telegraph posts "a," "b," "c," "d," the point "e," where the railroad enters the cutting, and "f," where the hedge runs up the hill from the highest point of the cutting. These points should be marked in lightly, and if necessary a pencil note made stating what they are. We have now sufficient points to go on with.

Next take vertical measurements to the bottom of the railway embankment, and to the hedges bordering the road in the foreground. Notice that the bottom of the embankment and lower edge of the copse is horizontal till it reaches a point below "b," when it runs upwards and joins the "initial" line just beyond "a."

The bridge under the railway is about half-way between the poplar and "d," and the left edge of the "Three acre copse" starts a little to the right of the same point. The upper line of this copse passes through "e" and just below "f." The farther side of the cutting starts a little nearer "d" and passes through "f."

From "f" a vertical measurement should be made to the top of the hill, which can then be drawn in down to the poplars, noting its general slope is convex. The hedges, trees and bushes on this hill can also be drawn.

From "a" take a measurement to the top of St. Martin's Hill, and note that it cuts Hangman's Hill straight above "d"; this hill can then be drawn in.

The distant line of hills are similarly noted to be, the left of them straight above "c," and the right above a point half way between "d" and "e."

Put in the line of hedges on St. Martin's Hill, and remember they give a very good idea of the shape of the ground. If you notice, the hedge running from "c" to the top of the hill makes a slight downward curve, showing the slope to be concave.

The line of poplars appear to get smaller and smaller as they get farther off; the same applies to trees in hedgerows. If you are not certain how high to draw them, take one or two vertical measurements of actual trees at various ranges.

We have already got the position of the road in the foreground, having taken a vertical measurement to it, and it lies quite parallel to the railway. Get in the position of the culvert on the left and the three elm trees. The stream on the left runs to the bridge under the railway, and from the left elm a hedge runs to the "Three Acre Copse," meeting where the centre elm's top branches cut out the view. The height of the elms can be measured or judged with reference to other points; for instance, the two left ones coincide with the top of the railway embankment.

So far all the work should be put in lightly in pencil. Now start to finish up, which can be done either with pen or pencil. The former is, of course, more lasting, but with pencil work, if the sketch is well soaked in water, or, better still, in milk or sugar and water, you will find it won't smudge very much.

Plate XXXVII.

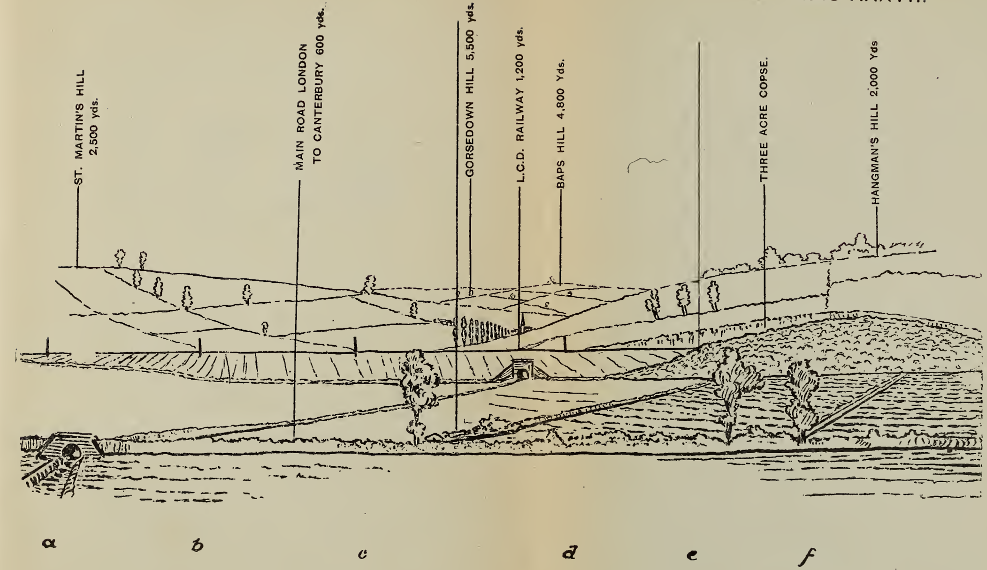


fig 2

View looking S.W. from △ mark on Cæsar's Camp Hill, Ashford.

Ranges by Mekometer.

In finishing there are three points to remember. The foreground must be dark and bold, the distant hills firm but lightly drawn, and the middle distance toned down between the two.

Certain trees have peculiar formations. Those most commonly met with are illustrated below. (*Fig.* 3).

FIG 3

NOTE.—Some kind have the spikes running up and some down

There is another method for drawing panorama sketches, and this is to use a plane table and clinometer. This method is not so practicable as the former, and I advise you to stick to the first method.

Rule a line across your paper. This line represents the horizon line, *i.e.*, an imaginary line which is in reality level with your eye. The points in nature which are level with you can be found out with the clinometer.

Mark a point 24 inches from the centre of the horizon line and stick a pin in. From this point take rays to any objects. If they are level with you their position will be where the rays meet the horizon line, if not their position will be straight above or below that point.

To find the exact position take the angle of elevation or depression with your clinometer, and for every degree mark off ·4 of an inch. A strip of paper with divisions of ·4 inches marked on it will save time, and the position of any object can be found at once after the point where the ray meets the horizon line is marked.

Sufficient points having been fixed fill in the detail and finish up as before.

If a point 18 inches from the "horizon line" is taken mark off ·3 inches for every degree of clinometer reading, if 12 inches from the line ·2 inches for each degree.

A combination of these two methods may be used. For instance in Fig. 2 the horizontal distances might be made with a pencil, and the vertical measurements taken with a clinometer.

When taking the measurements with pencil held at arm's length (which is about 24 inches), ·4 inches must be marked off for each degree.

If this makes too big a sketch hold the pencil not so far out, and to ensure keeping it the same distance from the eye for each measurement, take a piece of string with 2 knots in it, 18 or 12 inches apart. Put one knot between the teeth, and the string being taut, hold the other in the pencil hand. For each degree read on the clinometer, mark off ·3 or ·2 inch respectively.

A small sketch can be drawn, and measurements taken at arm's length, as follows:—Use your protractor, make the zero point on one of the scales (say 6 inch to 1 mile) correspond with one object and note the distance to the other object. Say it reads 1,000 yards, and you wish to make your sketch half this size, divide all horizontal and vertical measurements by 2. If you have no protractor with you a stiff piece of paper with any small equar divisions will do as well.

Small freehand or thumb-nail sketches, used for illustrating road reconnaissances or sketches, are drawn in a similar way to panoramas.

Measure the full horizontal distance of the building, etc., to be sketched and then reduce it to a convenient size as described above.

Judge a spot equal to the height of one's eyes on the part of the building nearest to one, and take vertical measurement above to the top and below to the ground line. Also get in the position of the tops and bottoms of windows, doors, etc., and width of same.

This is simple enough if the building is directly facing one, but when it stands at an angle, a certain amount of "perspective" must be used. The word perspective is inclined to make some "shy" at the work, so let us see if we cannot arrive at the desired result without using it. Hold the protractor or straight edge 2 or 3 inches from the eye, and corresponding with the line of the eaves (Fig. 4,

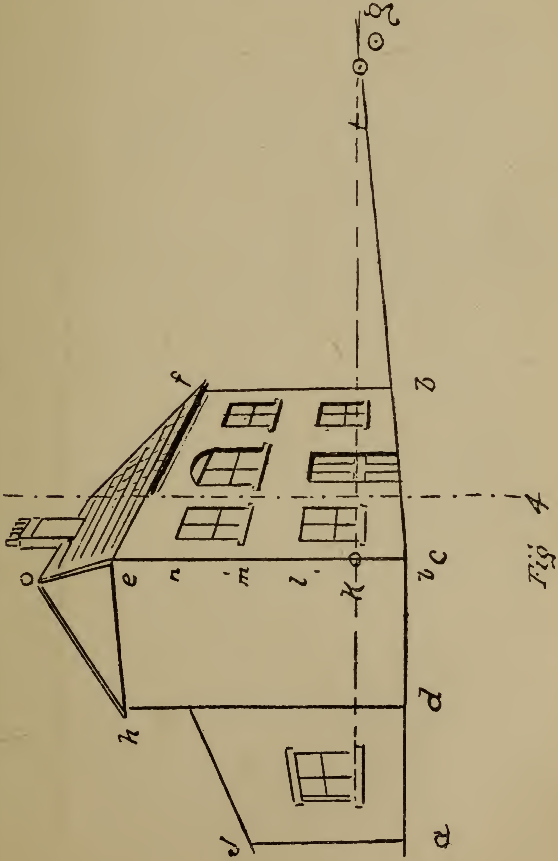


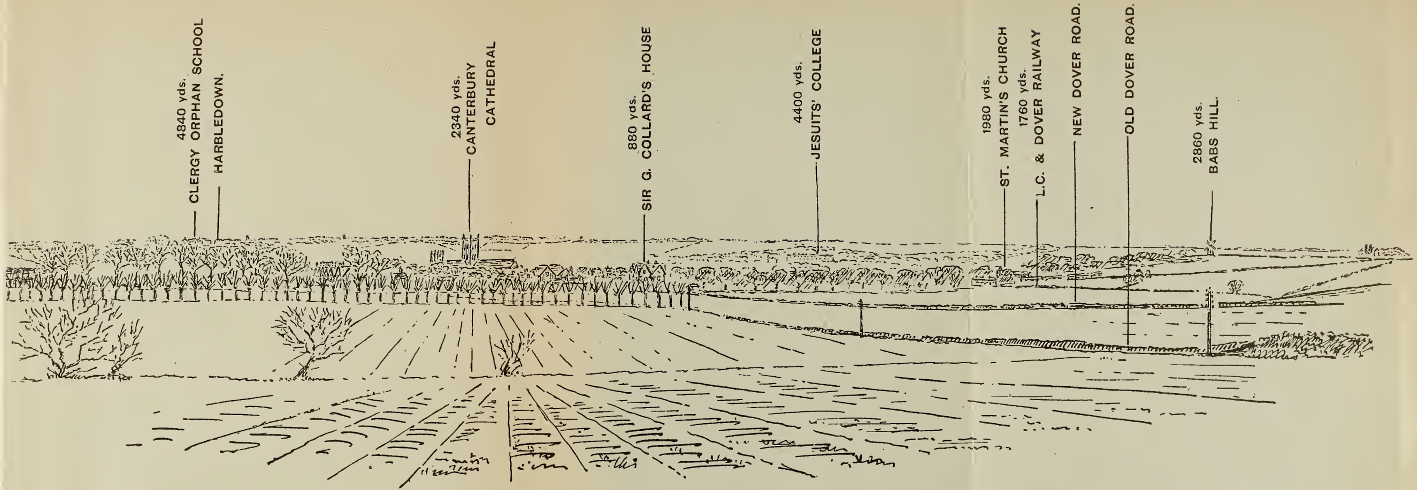
Fig. 4

e.f.). Note the continuation of this line, *e.f.* meets at *g.* Similarly note the continuation of the ground line, *c.b.g.* These 2 lines meet in *g*, a point on a horizontal line drawn through the spot which is level with one's eyes. This spot must be noted, it may be a certain leaf on a bush, stone, or branch of a tree. Take a horizontal measurement and fix it on the sketch. The lines *ng*, *mg*, *lg*, *kg* from the nearest corners of tops and bottoms of windows, doors, etc., will all meet in the point *g.*

Sufficient points fixed fill in the detail, such as chimney, tiles, window panes, but avoid shading. Finish up noting where the strongest light comes from and darken in the shadows. Half of Fig. 4 has been finished to show what is wanted, the other half being left to show the sketch under construction.

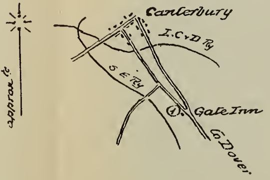
In conclusion please remember these notes are not for the artist, they may probably offend his method of working, but if they help the man who has never attempted a panorama sketch, then, indeed, their object has been achieved.

Plate XXXVIII.



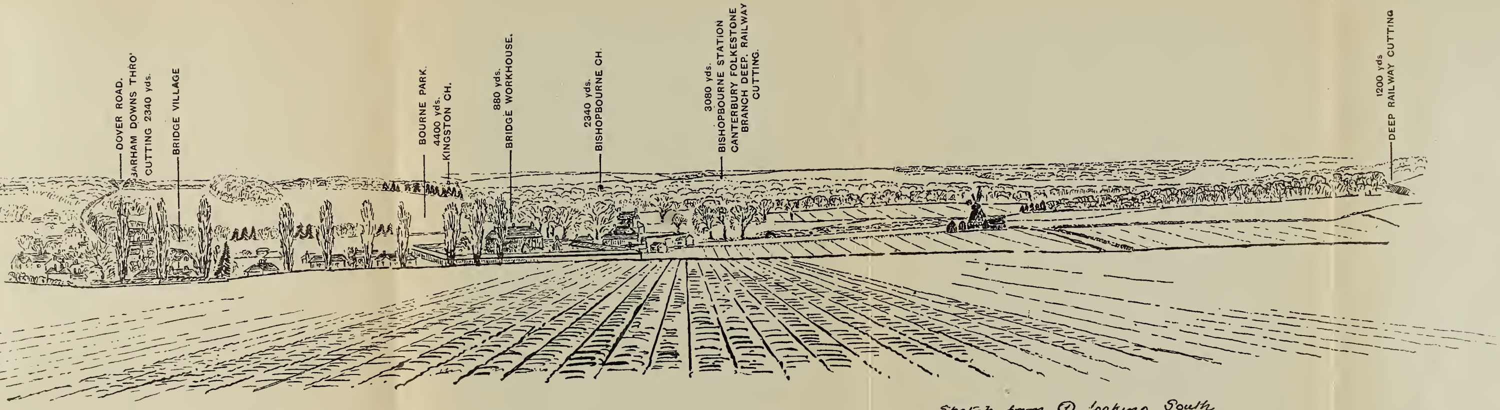
from Gate Inn on Dover Road ① looking Northward
Ranges from Bartholomews half inch to mile map

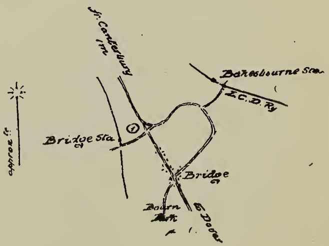
-fig 5-



R. J. Pearson Captain
The Buffs

Plate XXXIX.





Sketch from ① looking South

Ranges taken from Bartholomews half inch to mile map

R.P.Pearson Captain
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