MILITARY SURVEYING

AND

FIELD SKETCHING.

SKETCHING WITHOUT INSTRUMENTS,
SCALE OF SHADE,
EXAMPLES IN MILITARY DRAWING,
RECONNAISSANCE OF POSITIONS, ROADS, ETC.,
MEASUREMENT OF HEIGHTS AND DISTANCES,
ETC. ETC. ETC.

BY

MAJOR W. H. RICHARDS,
Fifty-fifth Regiment.

CHIEF GARRISON INSTRUCTOR.
LATE INSTRUCTOR OF MILITARY SURVEYING, ROYAL MILITARY COLLEGE, SANDHURST.

SECOND EDITION.

Published by Authority.

LONDON:
WM. H. ALLEN & CO., 13, WATERLOO PLACE,
PALL MALL, S.W.

1875.

London: Wm. H. Allen & Co., Printers, 13, Waterloo Place, Pall Mall, S.W.

PREFACE.

THIS edition has been specially preparèd for the course of Garrison Instruction. Chapters on Reconnaissance, the Measurement of Heights and Distances, and other fresh matter have been added to the first edition : those on the application of the Theodolite to Military Surveying, on Instrumental Contouring, Levelling, &c., have been suppressed as beyond the limits of the course.

I am indebted to Captain Fothergill, R.M.A., F.G.S., Royal Military College, for the plates of hâchure drawing, and also for conducting the Work through the Press.

CONTENTS.

		PAGE
SECTION I.	—Introductory Remarks—Scales—Reducing and Enlarging .	1
II.	—Base and Triangulation	16
III.	—Measuring—Pacing	25
IV.	—The Prismatic Compass—Observation and Construction of the Triangulation—Interpolation—Magnetic Variation .	30
V.	—Traversing with the Prismatic Compass and Field Book—Plotting	42
VI.	—Sketching roads, &c.	48
VII.	—Representation of the features of the ground . . .	51
VIII.	—Hill Sketching with Clinometer	57
IX.	—Sketching without Instruments	73
X.	—Shading and Drawing from Models, &c.	77
XI.	—Sections	83
XII.	—The Pocket Sextant—Observation of the Triangulation .	86
XIII.	—Construction of the Triangulation by Scale of Chords, by Calculation	96
XIV.	—Problems in Heights and Distances—Tracing Figures on the Ground, &c.	104
XV.	—Reconnaissance	115

PLATES.

I.—Conventional Signs used in Military Topography	To face Title-page	
II.—Laying down a Triangulation	To face page	34
III.—Plotting from Field Book	" "	44
IV.—Sketching Roads	" "	48
V.—Representation of Hills	" "	52
VI.—Contour System	" "	58
VII.—Contour System	" "	63
VIII.—Contour System	" "	67
IX.—Contoured Hill Sketch	" "	69
X.—Sketch without Instruments	" "	73
XI.—Hâchure Drawing	" "	78
XII.—Triangulation with Sextant	" "	93
XIII.—Construction of Triangulation with large Protractor	" "	96
XIV.—Reconnaissance of Communications	" "	120
XV.—Sketch of Open Country—Running Triangulation	" "	124
XVI.—Examples in Military Drawing	end of Book	
XVII.— " "	"	
XVIII.— " "	"	
XIX.— " "	"	

MILITARY SURVEYING AND FIELD SKETCHING.

SECTION I.

INTRODUCTORY REMARKS.—SCALES.—REDUCING AND ENLARGING PLANS.

SURVEYING is the art of ascertaining by measurement the shape and size of any portion of the earth's surface, and representing the same on a reduced scale in a conventional manner so as to bring the whole under the eye at once.

The object of military surveying is to produce tactical sketches of the scene of action, showing the advantages it presents for attack and defence, or the capabilities for manœuvring or movement at the particular time.

Such sketches generally comprise small portions of country represented on a large scale; they must be performed rapidly, as their value depends upon their furnishing their information in time to allow of its being acted on. Attention is paid to objects in proportion to their tactical importance only; thus some objects receive more notice than in the most elaborate state maps; such as gentle undulations of the ground, their inclinations, relative heights and exact form; slight hollows, which may be all important as affording cover from fire, but which might escape the observation of a non-military man; and the present condition of the surface of the country, and the extent to which woods, hedge timber, &c., interfere with the view or with freedom of manœuvre.

Though extreme accuracy is unnecessary, these sketches must convey no false information; nothing that has not been actually seen must be represented, and the tendency to sacrifice truth to effect must be guarded against.

The most valuable sketches of positions and lines of communication, have frequently to be made under circumstances when it would be impossible to attempt deliberate measurements. On such an occasion, an officer who possesses trained powers of observation, will have as great advantage as in more deliberate work, arriving intuitively at just conclusions from slight indications, and knowing the objects to which attention must be directed, and those which he can afford to neglect.

The practice of military surveying is in great measure a process of development of the perceptive faculties, and whatever the natural aptitude for the subject may be, there are few officers who may not, by proper training, acquire a fair proficiency in this useful military accomplishment in these days, when mere draughtsmanship is of minor importance.

SCALES.

The construction of scales must be first mastered as essential in every part of the subject.

The "scale" of a plan is the proportion which it bears to the ground represented.

This proportion may be expressed by the "representative fraction," which has unity for its numerator, and for its denominator the number of similar units of measurement which this represents.

Thus, if an object, the actual length of which is a mile, be represented in a drawing by a line a yard long, the representative fraction would be $\frac{1}{1760}$, and if a foot long $\frac{1}{5280}$.

But in military plans it is customary to adopt a scale representing a *mile* by a certain number of *inches*, thus in speaking of a plan as being on the scale of 8 inches to a mile, that expression seems to convey a more tangible idea of its proportion than the equivalent mathematical expression $\frac{1}{7920}$. The representative fraction should, however, be also stated on the plan or sketch, as the mile and inch being arbitrary measures applicable to English operations only, will convey no idea of the relative proportions between English and Foreign plans in which the same standards of measure are not used.

The scale we should adopt at which to execute a plan will depend on the nature of the ground and the amount of detail required. For towns, from 30 to 120 inches to a mile is generally used; for sketches of military positions, from 6 to 12 inches to a mile; for a reconnaissance of a road or river, 2 to 4 inches to a mile.

The scale should be usually made from 3 to 6 inches long on paper.

For the construction of a scale—

Calculate how many inches and decimals of inches will represent a convenient number of the required units of measurement.

The number usually assumed is a multiple of ten units: as 500 yards, 80 feet, 1000 metres, 600 links, &c. This facilitates the division and subdivision of the line representing that distance.

The proportion is worked out thus:—

$$\text{Known number of units of measurement} : \text{Number of inches representing them} :: \text{Assumed number of units of measurement} : \text{Number of inches representing them.}$$

Ex. 1. Construct a scale of 6 inches to a mile to read yards.

Here the units to be represented are yards.

Mile.		Inches.		yard.		Inches.
1	:	6	: :	1	:	x

or,

Yards.		Inches.		yard.		Inches.
1760	:	6	: :	1	:	·0034

Then 100 = ·34

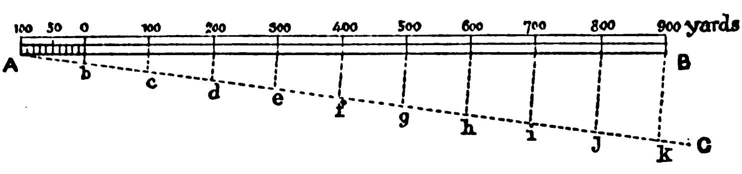
Assumed 1000 = 3·4

Take a line AB, 3·4 inches long, either from the artificial scale 30 of the Marquois scales, which is divided into inches and tenths, and on which a second place of decimals may be measured by estimation, or from the diagonal scale of inches engraved on the protractor.

Divide this line into 10 primary divisions of 100 yards each.

Fig. 1.

Scale 6 inches to a Mile. $\frac{1}{10560}$



This may be done by drawing another line A C at any angle with A B, on this lay off any 10 equal parts b, c, d, e, &c. Join B k and draw parallels to this from the points j, i, &c., intersecting A B in the required ten equal parts.

Subdivide the left division in the same manner into ten secondary parts each equal to 10 yards.

Ex. II. To construct a scale of 8 inches to a mile to read feet.

Here the units of measurement being feet,

Mile.		inches.		feet.		
1	:	8	: :	1	:	x

or,

Feet.		inches.		feet.		inches.
5280	:	8	: :	1	:	·00151

Then 100 = ·151

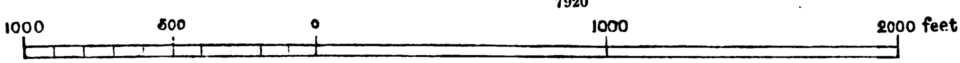
1000 = 1·51

Assumed 3000 = 4·53

Divide into 3 primary parts of 1000 feet, and subdivide the first into secondary parts of 100 feet.

Fig. 2.

Scale 8 inches to a Mile. $\frac{1}{7920}$



Ex. III. To construct a scale of chains 10 inches to a mile—in scales of chains the link is usually taken as the unit of measure.

Mile.		inches.		link.		
1	:	10	: :	1	:	x

or,

Links		inches.		link.		inches.
8000	:	10	: :	1	:	·00125

Then 1000 = 1·25

Assumed 3000 = 3·75

Fig. 3.

Scale 10 inches to a Mile. $\frac{1}{6336}$

Ex. IV. Construct a scale of 3 miles to ·764 inches.

Here the unit being miles,

Miles.		inches.		mile.		inch.
3	:	·764	: :	1	:	·255

20 miles = 5·1 inches.

To find the representative fraction of a scale, make the given number of units of measurement the denominator, and the number of inches which represents them the numerator. Reduce the fraction to one having its numerator unity.

Thus in Ex. I., scale 6 inches to a mile—

$$\frac{6\text{ in.}}{1\text{ mile}} \text{ or } \frac{6}{63360} \text{ R F } \frac{1}{10560}.$$

In Ex. IV., 3 miles to ·764 inches—

$$\frac{\cdot 764}{190080} \text{ or R F } \frac{1}{248795\cdot 8}.$$

To construct a scale when the representative fraction is given.

Make the denominator the first, and the numerator the second term of the proportion.

Ex. V. Construct a scale, of paces of 30 inches R F $\frac{1}{2074}$.

					Inches.	
2074	:	1	: :		30 :	·01446
					Paces.	
					10 =	·1446
					100 =	1·446
				Assumed length	400 =	5·78

Ex. VI. Construct scales suitable for sketching on horseback, it being found that the horse takes 118 strides cantering, and 270 walking a measured distance of 300 yards, and that the rider rises in the saddle 97 times in trotting the same distance.

$$\text{R F } \frac{1}{13260}$$

1st. Find the length in inches *of the* 300 *yards* at the representative fraction.

				Yards.	
13260	:	1	: :	300	:
				Inches.	Inches.
				= 10800 :	·8145

Then the known number of units (118 strides cantering, 270 walking, and 97 times of rising in the saddle), are each represented by ·8145 inches.

Cantering.		Inches.		Cantering.		Inches.
118	:	·8145	: :	1	:	·0069
				100	=	·69
				Assumed 800	=	5·52

Walking.		Inches.		Walking.		Inches.
270	:	·8145	: :	1	:	·00302
				1000	=	3·02
				Assumed 2000	=	6·04

Rising in saddle.		Inches.		Rising in saddle.		Inches.
97	:	·8145	: :	1	:	·0084
				100	=	·84
				Assumed 600	=	5·04

Ex. VII. A sketch is found having no scale or R F marked on it. The distance between two objects represented in it as 2·73 inches apart is measured on the ground, and found to be 765 yards. Construct a scale for the sketch.

Yards.		Inches.		Yard.		Inch.
765	:	2·73	: :	1	:	·00357
				100	=	·357
				Assumed 1500	=	5·355

$$\text{The R F is } \frac{2\cdot73 \text{ in.}}{765 \text{ yds.}} \text{ or } \frac{2\cdot73}{27540} = \frac{1}{10087\cdot9}$$

or,

Yards.		Inches.		Yards.		Inches.
765	:	2·73	: :	1760	:	6·28.

Scale, 6·28 inches to a mile.

If unprovided with instruments, a scale may be improvised for use, the value of which may be subsequently ascertained.

Divide the edge of a card into *any equal parts*, to represent hundreds of yards.

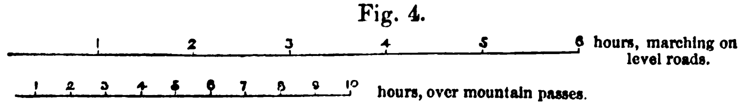
This on subsequent examination is found to be, say, 3·75 inches long, and to represent 700 yards.

Then (as in Ex. VII.), the sketch is drawn on the scale of 9·428 inches to a mile.

Scales are called "comparative scales," when they express the same proportion in different units of measure. As, for instance, if a scale of yards be constructed whereby to examine a foreign plan, it is comparative to the scale of that plan; or a plan might have scales of yards, of feet, and of links, attached to it, comparative to each other, that is, having the same representative fraction as in Ex. VI.

It must be remembered that in military operations *distances are to be measured by the time taken in traversing them.* In mountain districts, where the time occupied in marching distances will vary greatly with the nature of the ground, a scale of time, framed on our experience, will be a most useful addition to a plan or map.

Fig. 4.



In the foregoing examples of plain scales the subdivisions are secondary only. If it is required to show a third subdivision, the scale is constructed on the diagonal principle, so as to measure minute quantities, thus:

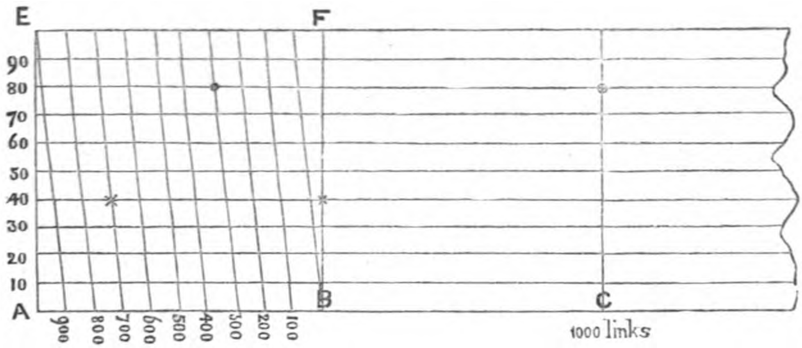
Ex. VIII. Required a scale of chains to show 10 links. Scale 12 inches to a mile.

Links.		Inches.		Links.		Inches.
8000	:	12	: :	1000	:	1·5
				Assume 3000	=	4·5

Take A D = 4·5 inches and divide it into 3 parts of 1000 links each, B, C, D.

Fig. 5.

Scale 12 inches to a Mile. $\frac{1}{5280}$



N.B.—" D " is not shown for want of space.

Draw 10 lines parallel to A D at any convenient equidistance and raise perpendiculars to A D at A, B, C, D. Subdivide the left division A B and E F into 10 parts of 100 links, join these points of division diagonally and number the scale as shown; then, if a distance of, say, 740 links is to be taken, we place the points of the compasses at x, x; for 1380 links at o, o.

Ex. IX. Construct a scale of yards, feet, and inches.

$$R\,F\ \frac{1}{45}$$

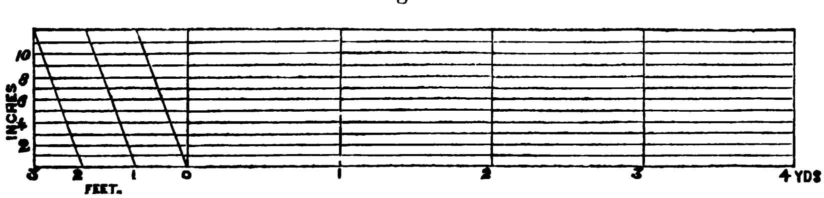
Here the primary divisions are yards, the secondary feet, and the diagonals show inches.

$$45 : 1 :: \overset{\text{Yard.}}{1} : \overset{\text{Inch.}}{x}$$

$$= \overset{\text{Inch.}}{36} : \cdot 8$$

Assume 5 yds. = 4 inches.

Fig. 6.



As, in sketching, the measurements are made by pacing in yards, one or two convenient scales, usually 6 and 8 inches to a mile, are engraved on the ivory protractor.

If sketching on a scale which is not engraved on the protractor, we may still use these scales for any of their multiples or measures. From the scale of 6 inches to a mile we may take 3, 12, 18, &c., from that of 8 inches to a mile, 4, 16, 24, &c.

For example, an object 300 yards long would be represented in a plan of 8 inches to a mile as of a certain length.

If the plan were 16 inches to a mile it would be represented as double that length, or the same thing as 600 yards on the scale of 8 inches to a mile.

The method of applying the scale in the field for sketching on a scale which is a multiple of one of those given on the protractor then is—Multiply the actual dimension by the required increase of the scale, and take it from the scale as it stands.

All chance of error on this account may be easily avoided by constructing the required scale on the edge of a stout card; and the beginner will probably find that by using this instead of the scale on the protractor, he will save time and trouble.

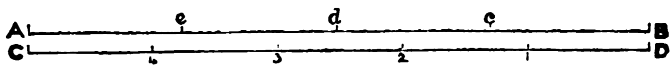
Measurements in the field should be always taken direct from the scale by applying it to the plan; compasses should not be used for the purpose.

THE VERNIER.

The vernier scale is a contrivance for minutely subdividing a graduated scale. Its principle is this :—

If a line A B be divided into any number of equal parts, say 4; and a line of equal length C D be divided into 5,

Fig. 7.

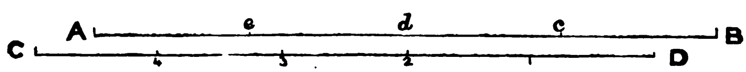


Then, each division in C D will be smaller than each in A B by $\frac{1}{5}$th; and C D will be a vernier scale to read fifths of the primary divisions.

If the line C D be moved along A B until the division 1 coincide with *c*, D will have passed over $\frac{1}{5}$th of a primary division from B.

If the vernier scale be moved until 2 coincides with *d*

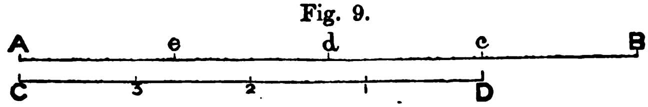
Fig. 8.



D will have passed over $\frac{2}{5}$ths of a primary division from B, and so on.

To construct a vernier to read fourths of the same primary divisions. Take a line C D equal to three of these A *c*.

Fig. 9.



Divide it into 4 parts, each of these will be $\frac{1}{4}$th less than each of the primary divisions; and if the vernier scale C D be moved, the successive contacts of 1, 2, and 3, with the primary divisions *d*, *e*, A, will indicate how many fourths D has moved from *c*.

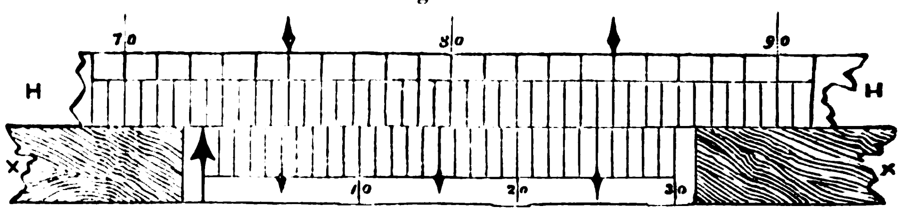
Ex. X. Construct a vernier to read hundredths on a scale of inches.

Take a line $\frac{9}{10}$ths of an inch long, and divide it into 10 parts. This will read hundredths on a scale divided in inches and tenths.

In the pocket sextant the vernier is constructed to subdivide the divisions of the arc (each equal to $\frac{1}{2}$ a degree or

30 minutes) into minutes; therefore an arc equal to 29 of these primary divisions is taken and divided into 30 equal parts, each of which is $\frac{1}{30}$th (or one minute) less than the primary divisions.

Fig. 10.

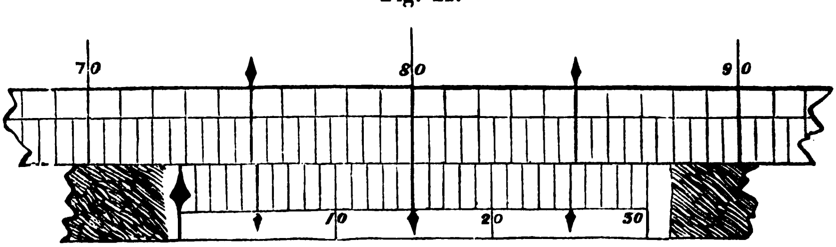


Vernier Scale.

To read off the angle recorded by the vernier. First look at the zero or arrow of the vernier, and notice what degree of the arc it has last passed (from left to right). In the figure this is 72 degrees. Now examine the divisions of the vernier to find the minutes. We find that only one exactly coincides with one on the arc (the 23rd). The angle then is 72° 23′.

But if the zero of the vernier has passed one of the half degrees of the arc (Fig. 11), we must add the number of minutes denoted by the coincidence of the lines on the vernier and the arc, to the 30 minutes or ½ degree already recorded by the zero of the vernier. Thus, as the vernier shows 15 minutes, the angle recorded is 72° 45′.

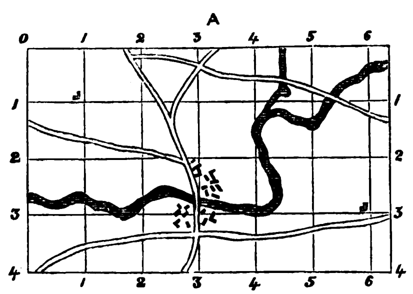
Fig. 11.

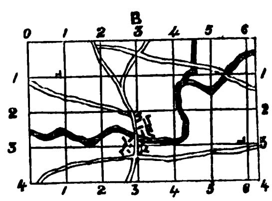


Vernier Scale.

REDUCING OR ENLARGING PLANS.

Supposing that a fair copy, to the scale of 6 inches to a mile, is required of the sketch previously mentioned as drawn by means of a make-shift scale.





Draw squares on the original (A) of any convenient size, say 100 yards, *by the scale that was used.*

Prepare the sheet on which the copy is to be made (B) with squares of 100 yards, on the scale of 6 inches to a mile. It can then be easily filled in by eye, objects being placed in the smaller squares in the same relative position that they occupy in the larger.

Ex. XI. A plan on the scale $\frac{1}{60000}$ is to be copied at $\frac{1}{25000}$.

Draw squares on the original with sides of, say, half an inch.

For the copy draw the same number of squares ; suppose there are ten, those on the original occupy 5 inches, therefore these will occupy $\frac{60000 \times 5}{25000} = 12$ inches.

Divide this into 10 for the size of the squares.

Ex. XII. A French plan, the scale of which is 4·5 inches long, and consists of 700 mètres, is to be copied to the scale of 6 inches to a mile. The mètre is 1·0936 yard.

R F of plan

$$\frac{4{\cdot}5 \text{ inches}}{700 \text{ mètres}} = \frac{4{\cdot}5}{700 \times 1{\cdot}0936 \times 36} = \frac{1}{6124{\cdot}16}.$$

R F of copy $\frac{6}{63360} = \frac{1}{10560}$.

If we draw 1 inch squares on the original,* 10 squares on the copy will occupy $\frac{6124{\cdot}16 \times 10}{10560} = 5{\cdot}79$ inches.

QUESTIONS FOR PRACTICE.

1. Construct a scale of miles and furlongs

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

2. Construct a scale of 6 miles to ·73 inch, and state the representative fraction.

3. A plain scale of 200 feet to an inch, also a diagonal scale of the same to read units.

4. The wheel of a waggon performs 170 revolutions in a measured distance of 860 yards. The number of horse's paces in the same distance are, cantering 415, trotting 604, walking 802.

Construct suitable scales, 7 inches to a mile.

5. A sketch of the Russian position on the north side of Sevastopol was found on the body of an officer killed in a sortie. The scale on the sketch was 5·15 inches long, and represented 2000 archines.

* In order to avoid defacing valuable plans, I have found the following a good method. Rule a sheet of glass with inch or half inch squares in ink, and lay this on the original, the copy being prepared in pencil with squares similar, or in proportion to, the proposed reduction or enlargement. Two pencil dots on the original, corresponding to the corners of the glass, enable one to replace it correctly if required.

Construct an English scale for the sketch. An archine is ·777 yards.

6. Construct scales R F $\frac{1}{12672}$ and $\frac{1}{5068800}$.

7. Construct a vernier to read thousandths of a foot.

8. Construct a triangle of which the side AB is 3·25 and AC 2·75 inches long, and the angle ACB 89°. What would be the scale of the plan if it took 1 hour 23 minutes to walk from C to B at the rate of 3½ miles an hour ?

9. What is the smallest fraction of an inch that can be read on a diagonal scale.

1st. When the primary divisions are inches.

2nd. When the primary divisions are half inches.

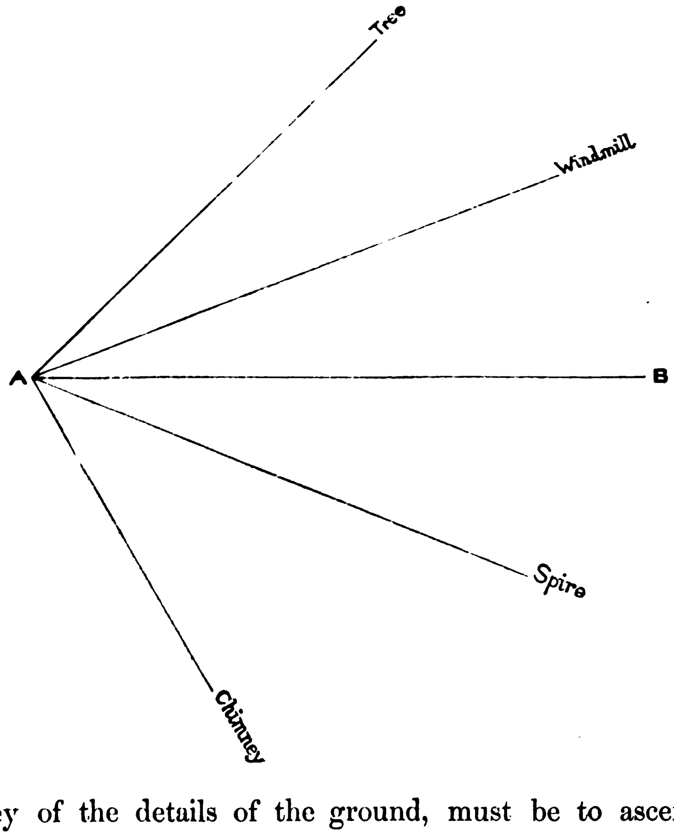
3rd. When the primary divisions are quarter inches.

SECTION II.

BASE AND TRIANGULATION.

In surveys and sketches of extensive positions where accuracy is desired, the first step, before proceeding to the

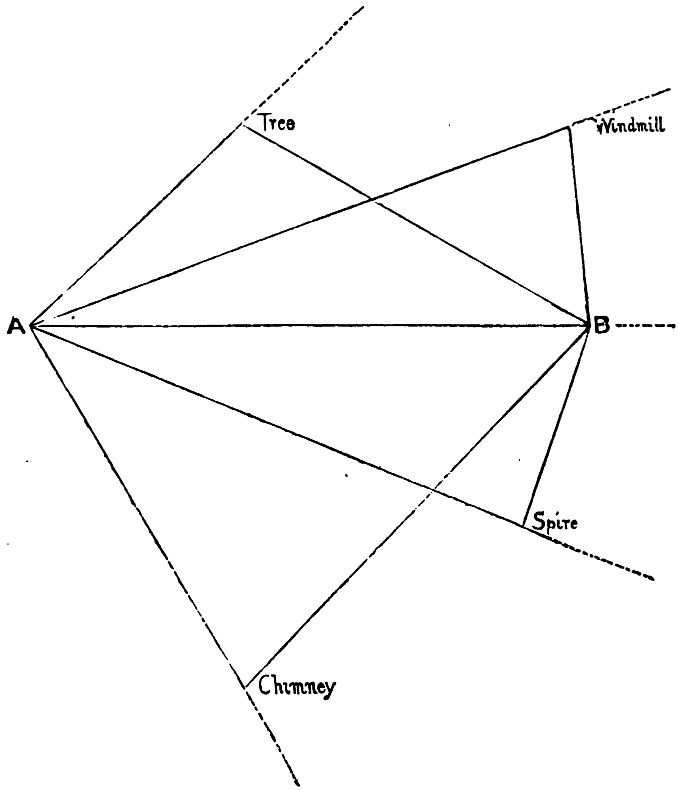
Fig. 12.



survey of the details of the ground, must be to ascertain and lay down on the plan with precision the relative positions of a few conspicuous objects throughout the extent of the ground. This is performed by Triangulation, in describing which here, no mention will at first be made of any instrument, for the sake of placing the problem in its simplest form.

If we stand at a commanding point of view, whence we can observe the direction of objects in the surrounding country, and, taking a sheet of paper, make a point A, Fig. 12, upon it to represent that at which we are standing, we can from this point upon the paper draw lines towards the objects we have chosen.

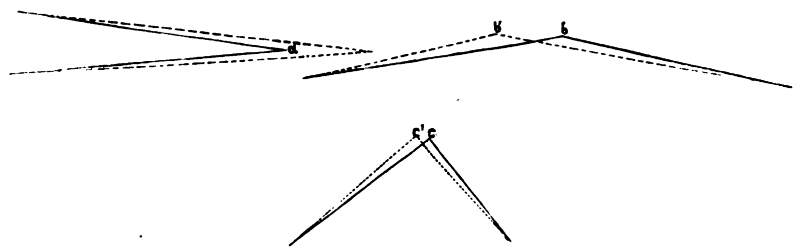
Fig. 13.



Suppose, now, we measure the distance in a straight line to any one of these B, and placing the sketch there, so that the line B A is directed on A, draw lines towards the same objects, the intersection of these with the relative lines from A, will fix their position, and the points thus found on our paper will have a similar position to that of the objects in the surrounding country. These points are termed *Stations.*

It must be observed that the slightest inaccuracy in the direction of lines intersecting either in a very acute or obtuse angle (*a* and *b*) Fig. 14 will greatly alter the position of the point of intersection, and that the same amount of inaccuracy will displace the point least when the lines intersect at a right angle (*c*).

Fig. 14.



In order to insure accuracy in the position of Stations therefore, we must consider the necessity of obtaining good intersections, and if the Stations thus fixed by well proportioned triangles constructed on the original base, do not extend over the whole tract of country to be surveyed, we may construct other triangles upon these (the sides of each triangle furnishing bases for fresh ones) and build triangle on triangle until the network covers the required space.

These stations provide us with starting points from which to commence the survey of the details of the ground, to check the correctness of the work as it proceeds, and to facilitate its progress generally.

The measurement of the original base is the most important part of the survey, as upon its accuracy depends that of every subsequent part of the work.*

The length of the base (and consequent size of the triangle) must be proportioned to the extent of country to be surveyed, but as a general rule, the longer the better. The length of the Base for a survey of 50 square miles would be from 1 to 3 miles ; for 10 square miles, $\frac{3}{4}$ to 2 miles; 1 square mile, not less than 600 yards. If shorter bases be used, the number of well proportioned triangles to cover the ground would be greater, and the chance of error would be increased consequent on the necessity of a greater number of observations.

The ground on which the base is measured should be tolerably level, in order to avoid the calculations necessary in hilly ground for the reduction of the measurements to their true horizontal length; gentle slopes, however, up to about 4° or 5° have a comparatively slight effect on linear measurements, and if the ends of the base line are otherwise well situated (*i.e.*, so as to command an unobscured view of the surrounding country) the existence of such undulations in the intervening ground need not be considered a great drawback, since, in the limited extent of country which an officer's sketch will usually comprise, there will rarely be found a perfect position for a base.

The base should be laid as near the centre of the proposed survey as convenient, since the liability to inaccuracy in the

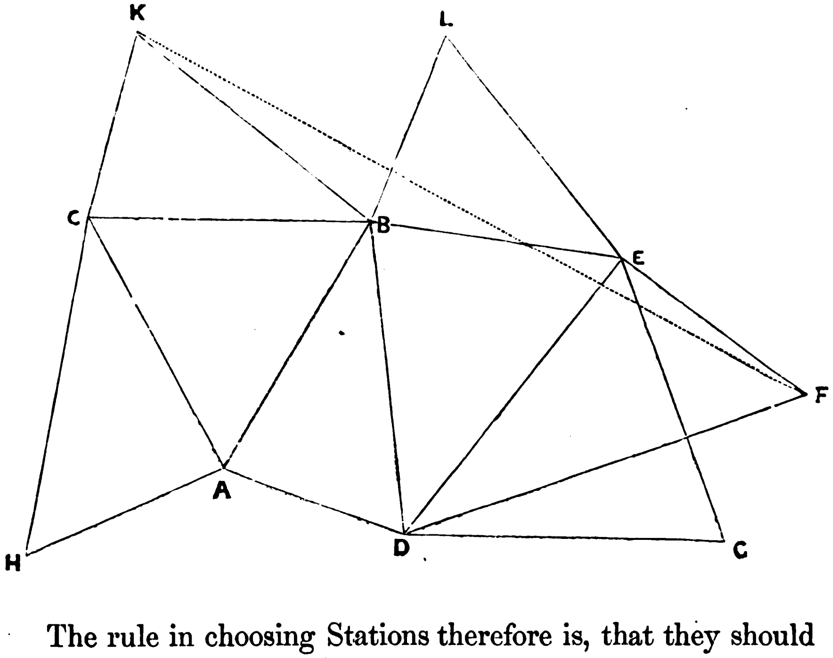
* In extensive National surveys this operation is performed with great labour and cost, with a variety of measuring instruments least susceptible to atmospheric influence, such as rods of glass and deal, steel chains and compensating bars, consisting of bars of different metals so joined together that the variations of temperature acting upon them in different known proportions, they may, by their construction, preserve minute marks at their extremities, at the same distance from each other, under all atmospheric conditions. It would be out of place here to enter into any details of operations of this important nature—a perusal of the subject in any work on Geodesical Surveying will be found interesting.

triangulation increases with the distance from the original base.

It has been remarked that in selecting stations we must be influenced by the consideration of the necessity of securing a good intersection at each: if the triangulation is, however, to be carried out to any extent, we must be careful that, in following out this idea, we do not on the other hand reduce the size of the triangles.

The best form of triangle is the Equilateral, as the intersection at an angle of 60° is sufficient to determine the Station with accuracy, and without a loss of length of base for the subsequent triangles.

Fig. 15.



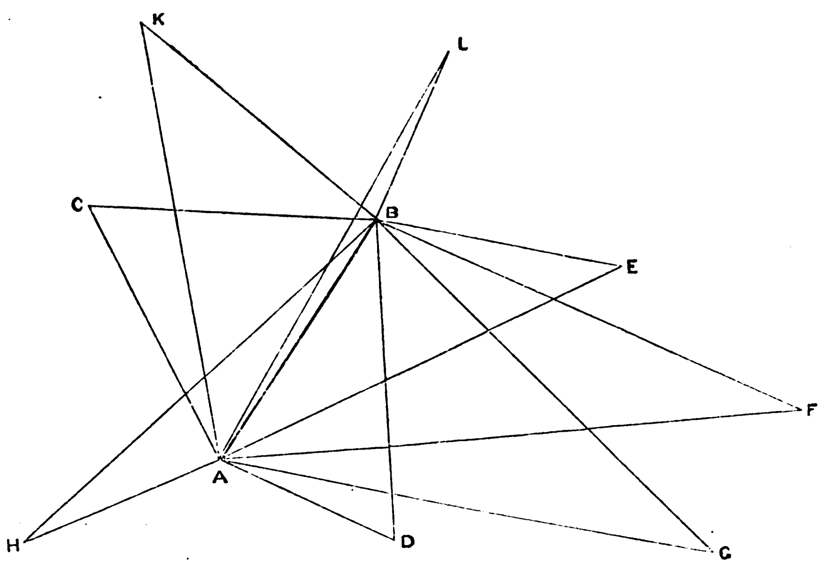
The rule in choosing Stations therefore is, that they should not be at a much greater distance from the ends of their base than the length of that base, and that they should not lie much behind either end of it.

The accompanying Figures are shown as an illustration of these principles, being a badly and a well arranged triangulation of the same Stations.

In Fig. 16, the common error of intersecting a great number of Stations from the ends of the original base has produced several badly formed triangles, the intersections at H, K, L, F & G, being too acute.

In Fig. 15, the Stations C and D only were determined from the original base, the other points being fixed by successive triangles of good form constructed on these.

Fig. 16.



We may occasionally verify the accuracy of the triangulation by observing the direction of a Station from two or three other Stations, and if these lines converge on the same point when laid down on paper, it is a satisfactory proof not only of its accuracy, but of that of each of the Stations whence these observations are made. When good instruments are used, and proper care taken, this test need only be occasionally applied. For instance, if an observation from F be found to pass through K, Fig. 15, it is a sufficient proof of the accuracy of the whole series of triangles on each side of the original base from which these two points are derived. This is termed the *Angular test.*

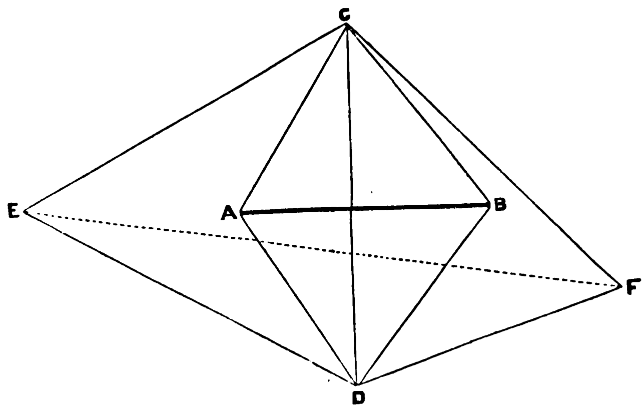
The *Linear test* or measurement of a "base of verification" consists in measuring on the ground a side of a triangle, or distance between two Stations remote from the original base, and comparing this measurement with the corresponding calculated length, this test is applied in important surveys where the length of the sides of the triangles is calculated trigonometrically.

It is a common error to suppose that the value of a triangulation is increased by having a great number of Stations; the principal Stations should, on the contrary, be few and equally distributed, the crowding of triangles merely causes confusion where simplicity is of importance. Should it subsequently be found necessary to determine any Station, it is done by secondary triangles formed within the principal ones.

For sketching purposes, it is unnecessary to have stations nearer *than* 2 *or* 3 *inches from each other on paper*, so that when working on 24 inches to a mile we should have them as close as 200 or 300 yards on the ground, whilst if sketching at the scale of 4 inches to a mile, we should select suitable points about $\frac{3}{4}$ of a mile apart.

When we are unable to obtain a base of sufficient length (as, for instance, in a hilly piece of ground where it has to be taken along a valley) it is important that the size of the triangles be gradually increased, so as to obtain a greater length of base for the succeeding triangles, but in such a manner as to avoid the introduction of badly formed triangles. This may be performed in many ways, one of which is shown in the accompanying figure. Suppose A B to be the original base, the Stations C and D may be determined there-from; take C D as a fresh base of increased length, whence we may intersect E and F, and regard the line E F as another base, and so continue to increase the size of the triangles until the length of their sides is limited by the telescopic power of the instrument, or by the range of the human eye.*

Fig. 17.



It is necessary that each Station should belong to a triangle, when the observations are made with the view of obtaining the data for calculating the length of the sides, as is done in large surveys.

But when the prismatic compass is employed, there is no such necessity. The stations first fixed by intersections from the ends of the Base belong to triangles, but the remainder may be fixed with equal accuracy *from any Stations which will give a good intersection*, or it may be found convenient to

* In extensive surveys, distant observations are frequently made on clear nights, the locality of the Station being shown by a powerful light, such as the lime light, by means of which Stations have been made discernible in the hazy atmosphere of Great Britain at upwards of 70 miles distance.

The Helistrope, an instrument for concentrating and reflecting the rays of the sun in a given direction, is also used; by its assistance a very distant Station appears in daylight like a brilliant star, when much nearer objects are quite invisible through the obscurity of the atmosphere.

determine a Station by Interpolation. It must be remembered that the more directly Stations are derived from the ends of the Base the more are they to be depended on for accuracy; and therefore remote stations should be little used as points of observation.

In setting up marks for Stations, such as flags, &c., it must be borne in mind what appearance they will present from the point of observation. On high ground, where the Station will have a background of sky, a black object will be the most distinct, but in low ground, or where the background will be dark, a white object will show the best contrast.

It is comparatively easy to lay out a triangulation with judgment in a hilly country: but in a wooded flat country much difficulty will often be encountered in securing the visibility of Stations from the points of observation. The marks set up as Stations should be as high as possible, in order that they may not be obscured by hedges, underwood, &c.; in wooded country the best mark is generally a tall pole, with a disc or cross (black or white according to background) fastened in the top of a high tree, so as to stand above it.*

If a tree be chosen as a Station it will present so different an appearance from different points of view, that to ensure recognizing it we should fasten a flag or other mark in it. A piece of white paper fastened to a tree will generally last during the time required to execute a military sketch.

In sketches we overlook the corrections which are necessary in extensive works for the reduction of the sides of the triangles, on account of the spherical form of the earth; we regard the earth as a plane and the sides of the triangles as right lines.

* In the plains of India it was found necessary to erect towers from 30 to 150 feet high for observatories, in order to clear the vegetation and the sphericity of the earth.

SECTION III.

MEASURING.—PACING.

The chain is 22 yards long, including the handle at each end, and is formed of 100 long links joined by smaller rings, the length of the link being measured from centre to centre of these rings. The reason for adopting this length is its convenience in both linear and superficial measurements, as a mile contains 80 chains (8000 links), and an acre 10 square chains.

It is usual to describe all linear measurements as so many *links* when the chain is used.

At each 10 links in the chain, from both ends to the centre, there is a brass label with one, two, three, and four tongues; the centre or 50 links is denoted by a round label, this enables the surveyor to count at a glance the number of links measured, without the necessity of counting them from either end of the chain.

Fig. 18.

The chain is used by two persons, the leader and the follower. The leader is provided with 10 iron arrows, and walks in the required direction until nearly at the chain's length from the starting point, when the follower halts him, and dresses him in the proper direction by beckoning him to the right or left, allows him to draw the chain a foot or so beyond the starting point, and then pulls the chain steadily back until the outside of the handle touches the starting point, the chain being kept at fair tension, but without jerking or hauling. The leader then sticks an arrow in the ground, touching the inside of the handle at his end, making also a score on the ground in case of its being accidentally displaced, to avoid the occurrence of which the leader should give the chain a cast to one side each time he starts afresh, so that it may run forward clear of the arrow. The leader having placed his arrow, calls "all right," when they start again, the follower taking up each arrow when the leader has marked his end of the chain, *and not till then*, else they will risk losing their place.

When the leader has expended his 10 arrows, 1000 links is noted in the Field Book; he then measures out another chain and places his foot on the handle, and waiting till the follower comes up and returns him the arrows which he has picked up, he counts them to see that none is missing, *plants one at the spot*, and they start afresh. On arriving at the point to which the measurement is to be made, the leader passes it until the chain is adjusted by the follower, both then count the arrows in their hands to see that they have the ten between them; the entire length measured is thus reckoned; the number of times the 10 arrows have changed hands, as thousands of links; to which is added the number of arrows in the follower's possession (including that marking his end of the chain) as hundreds: and the odd number of links counted on the chain to the required point as tens and units.

All these details must be systematically carried out, and it is better that the chaining be performed by two persons only. Assistants often cause mistakes by mixing the leader's and follower's arrows.*

* It is evident that a measurement made on sloping ground as A B must be reduced according to the amount of slope to bring it to its true horizontal length or projection A C.

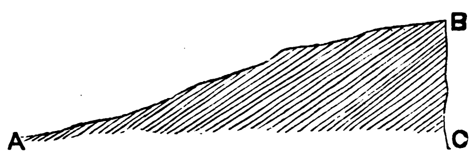
When time admits, the base should be measured two or three times and the mean adopted. When the chain is used the shortest measurement is generally the most correct.

As the chain is formed of a number of long links easily bent, and short unwelded rings liable to be expanded at the joints, it is necessary that its length should be occasionally tested by a standard chain, and whilst using it we should observe that it has not a "kink" or knot in it, and that none of the links are bent.

PACING.

In such surveying as an officer is generally called upon to perform, sketches of small positions, reconnaissances, &c., he will of course be unprovided with a chain and must deter-

Fig. 19.



The following table gives the necessary reductions to be made from each 100 links measured, for different inclinations.

Degs.	Links.	Degs.	Links.	Degs.	Links.	Degs.	Links.
5	00·4	14	03·0	23	07·9	32	15·2
6	00·6	15	03·4	24	08·6	33	16·1
7	00·7	16	03·9	25	09·4	34	17·1
8	01·0	17	04·4	26	10·1	35	18·1
9	01·2	18	04·9	27	10·9	36	19·1
10	01·5	19	05·4	28	11·7	37	20·1
11	01·8	20	06·0	29	12·5	38	21·2
12	02·2	21	06·6	30	13·4	39	22·3
13	02·6	22	07·3	31	14·3	40	23·4

It will be found in practice that (with the exception of the measurement of the base, where every means of securing accuracy should be adopted, or when the plan is on a very large scale) it will be unnecessary in military surveys to take these deductions into consideration at all, as they are usually quantities so small as to be inappreciable when drawn to scale on paper. The above table is formed by subtracting the natural cosines from radius.

mine the length of the base by pacing, or counting the paces of his horse.

The natural walking pace of different individuals varies, but most may train themselves into pacing yards with considerable accuracy. The regulation pace of 30 inches is well adapted for parade purposes, but if one walks in a free, swinging manner, the pace will usually be more nearly 36 inches. When walking quickly, though we seem to ourselves to be only taking our steps rapidly, we really increase their length also.

The best practice is to pace a measured distance of two or three hundred yards, altering the length of the pace till the distance can be covered in that number of steps within three or four.

This power of correctly measuring distance by pacing is of the first importance to a military surveyor, and should be frequently tested.

A mounted officer should ascertain the length of his horse's paces at the walk, trot, and gallop by trial over a measured distance. The walk will be found to be of quite as constant a length as the paces of a man.

We may occasionally obtain a very true estimate of distance on a road, by multiplying the measured circumference of the wheel of any vehicle by the number of revolutions it performs in traversing it. The revolutions of a moderate sized wheel drawn by a horse at a trot, are easily counted when a white mark is attached to one of the spokes.

Distances may be roughly judged by the time taken in traversing them, whether on foot or horseback.

The time taken in the transmission of sound, may be converted into distance, as sound travels 1118 feet in a second.

It is said that windows of houses may be counted at 4000 yards, and that horses and men present different specified appearances at certain distances; but as these phenomena depend on variable circumstances, they cannot be considered sufficiently definite for surveying.

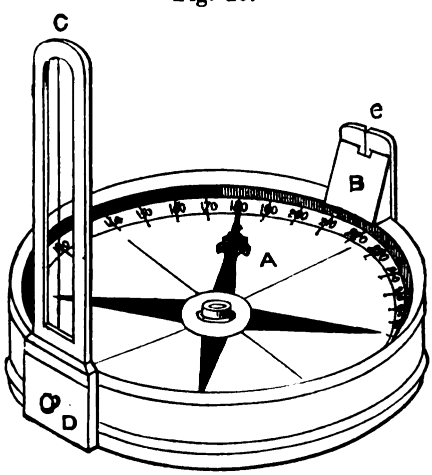
The military surveyor should endeavour from the commencement to educate his eye to the estimation of distances, not only of men or horses, but of all natural objects. This faculty, carefully cultivated, will go far towards enabling him to sketch rapidly and correctly.

SECTION IV.

THE PRISMATIC COMPASS.—OBSERVATION OF THE TRIANGULATION.—INTERPOLATION.

This instrument consists of a magnetic needle balanced on a pivot, and carrying a card A, or a metal ring divided into

Fig. 20.



360° and half degrees, this is contained in a box, at one side of which is a sight vane C; at the opposite a glass prism B, enclosed in a metal case, enables the divisions of the card to be read at the same time that the eye is close to the slit *e*, and is directed on the distant object.

Both the sight vane and prism may be turned down when not in use, and the whole shut in by a metal cover.

The Prismatic Compass gives us the *bearing* of a line, that is, the angle formed by the line with the magnetic meridian, *or angular distance from the magnetic north.*

To observe the bearing of an object. Turn up the prism and sight vane, hold the compass with both hands at some distance from the eye, watch the vibrations of the card, and by means of the knob D (which, when pressed, touches the edge of the card) check its swing if necessary. When quite settled, bring it up slowly to the eye, keeping it horizontal so that the card may not touch the glass cover, look through the slit *e*, and direct the hair of the sight vane C on the object, the bearing will then be seen on the card in coincidence with the hair. The graduation of the compass will be read from right to left like the hands of a watch.

Smaller quantities than half degrees can only be read by estimation. After a little practice, however, we may obtain bearings thus to within 15′ under ordinary circumstances.

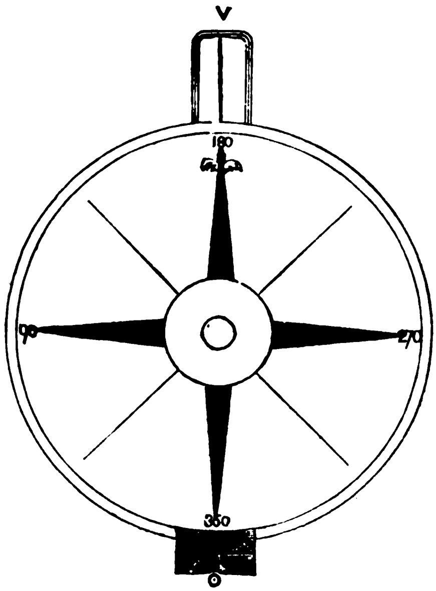
When once the compass is at the eye the spring D should not be touched, as to obtain a correct bearing the card must of course be perfectly free; but it should be at rest by itself before bringing it to the eye, else the hand and eye will be fatigued while watching for the cessation of its vibrations.

Sometimes the Prismatic Compass is screwed on a light tripod stand; but though at first sight this arrangement would seem advantageous as ensuring steadiness, yet it is questionable whether the slight motion of the hand is not of advantage in keeping the card *alive;* especially if the compass has been some time in use, and the point of the pivot has become somewhat blunted.

In windy weather it is necessary to sit or kneel, resting the elbow on the knee in order to obtain an accurate bearing.

It will be seen that in the card of the compass the order of the degrees is reversed, North is marked 180°, South 360°, East 270°, and West 90°. This is done that the degree due to the magnetic direction of the observed object may appear under the prism, thus, ⊙ being the observer's eye at the

Fig. 21.



prism, and V the sight vane directed on an object bearing North, the *South* end of the needle lies under the prism where the observer reads 360°, the degree denoting North.

The Prismatic Compass is not sufficiently accurate for the observation of an extensive triangulation. From local causes, which we have no means of ascertaining, we occasionally find that the compass gives a difference of bearing of as much as 2° or so in reciprocal observations of the same line from each end; and although the error is not usually so great as this, yet the possibility shows it to be too uncertain for such important work.

It is, however, sufficiently correct for military sketches of small positions, where an error of twenty or thirty yards in a mile is of no practical importance; or for filling in the details of a survey of which the triangulation has been observed with the sextant.

The whole of a sketch should be performed with the same compass; the bearings given by different compasses will be frequently found to vary as much as 3 or 4 degrees, and a party of beginners on comparing notes, and finding a discrepancy, are apt to strike a mean or adopt some of the bearings given by another compass, which course will insure error. The error in an instrument will not affect the correctness of the work (being a constant error), provided that the same instrument be used throughout: its variation being known, the true North can be laid down on the sketch. (Page 40).

No observation must be made with the compass in close proximity to any quantity of iron, such as a gate. When sketching along a line of railway, the effect of local attraction is to be avoided by taking the observations from a point 20 or 30 yards off on one side of it, and laying them down from a similar position on the sketch. An imaginary line, parallel to the railway, should be observed for its direction.

OBSERVATION AND CONSTRUCTION OF THE TRIANGULATION.

The ivory protractor is generally used to lay down the bearings observed with the Prismatic Compass.

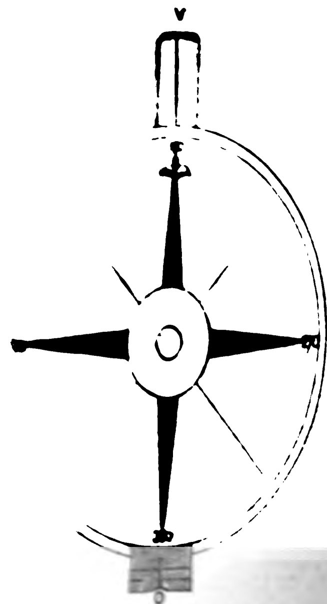
The degrees of the semicircle from O to 180 are marked on its outer edge, inside these the left semi-circle is continued from 180 to 360. The centre C is marked with a star or an arrow.

Smaller quantities than degrees when required must be laid down by estimation.

The paper used in sketching should be prepared with fine parallel lines about $\frac{3}{4}$ths of an inch apart, these represent magnetic meridians.

... the observed object may ap[pear]
... being the observer's eye at

Fig. 21.



prism, and V the sight vane directed on an object bear[ing]
North, the South end of the needle lies under the pri[sm]
where the observer reads 360°, the degree denoting North.

The Prismatic Compass is not sufficiently accurate for t[he]
observation of an extensive triangulation. From local caus[es]
which we have no means of ascertaining, we occasional[ly]
find that the compass gives a difference of bearing of as muc[h]
as 2° or so in reciprocal observations of the same line fro[m]
each end; and although the error is not usually ...
this, yet the possibility shows it to be ...
important work.

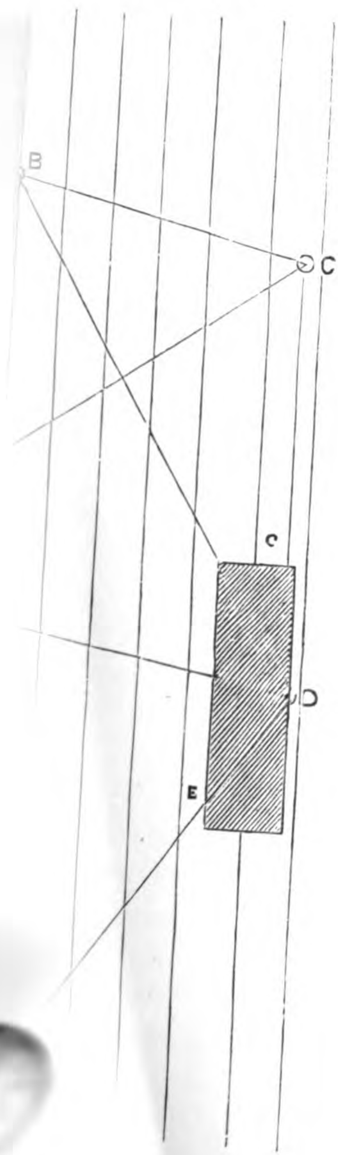
It is, however, ...
of small positions ...
a mile ...

... of a survey of which the ...
...ved with the sextant.
...e whole of a sketch should ...
...mpass; the bearings given by different ...
...equently found to vary as much as 3 or 4 ...
...arty of beginners on comparing notes, and ...
...ancy, are apt to strike a mean or adopt ...
...iven by another compass, which ...
The error in an instrument will not affect the ...
work (being a constant error), provided ...
must be used throughout: its variation ...
true North can be laid down on the ...
No observation must be made with the ...
proximity to any quantity of iron ...
sketching along a line of railway, the ...
tion is to be avoided by taking the ...
point 20 or 30 yards off on one side ...
down from a similar position on the ...
line, parallel to the railway, should ...
direction.

OBSERVATION AND CONSTRUCTION ...

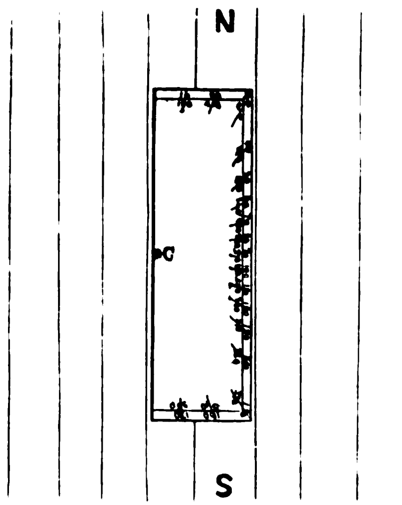
The ivory protractor is generally ...
observed with the Prismatic ...
The degrees of the ...
its outer edge, inside these ...
from 180 to 360. The ...
arrow.
Smaller quantities ...
down by ...

To face p. 34.



In laying down bearings, the protractor is adjusted North and South on the sketch as shown, Fig. 22, parallel to or

Fig. 22.



coinciding with these lines, the centre C at the spot where the bearing is to be laid down.

If the bearing is under 180°, the graduated edge of the protractor is to be to the right or East; if over 180°, to the left or West.*

Mark the required degree with a fine-pointed pencil.

The north side of the paper should be marked "N" before commencing, so that there may be no confusion as to the adjustment of the protractor.

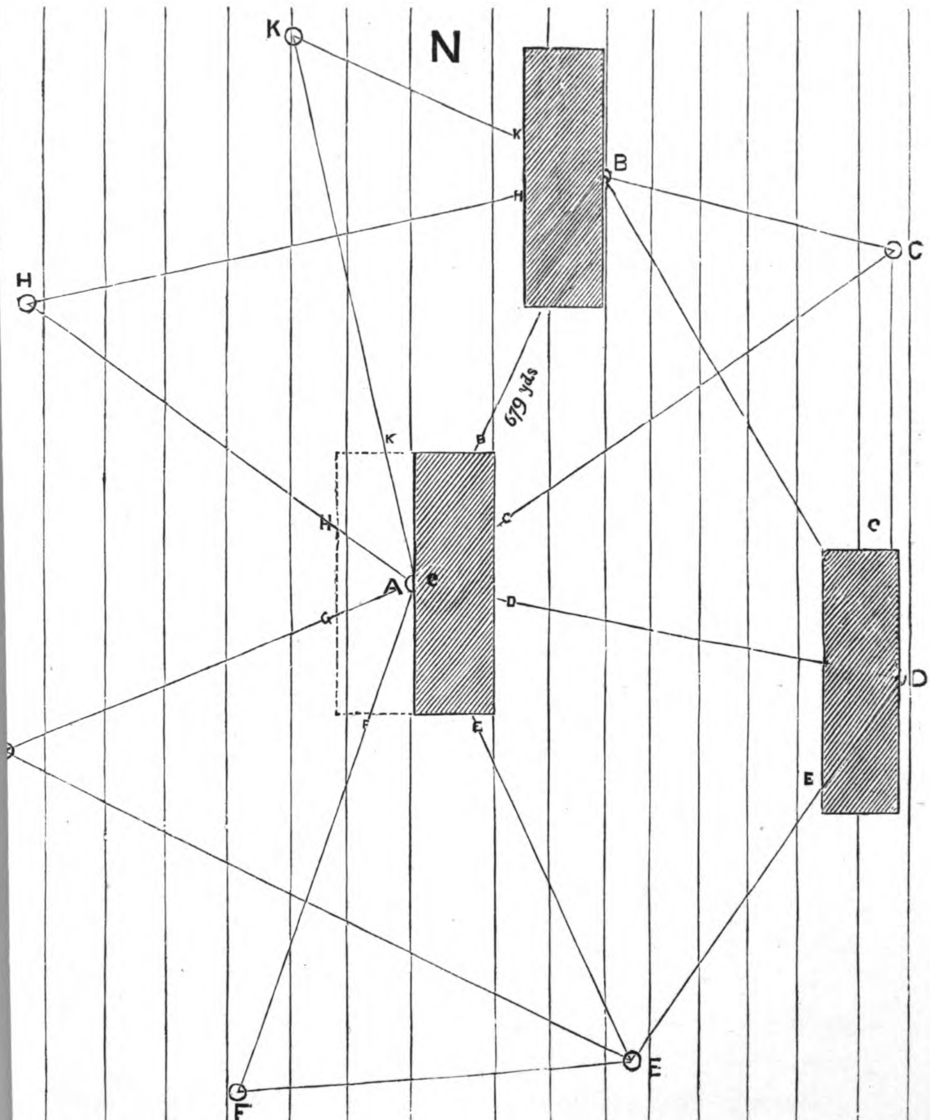
We will suppose that the triangulation for a position a mile square is to be constructed on the scale of six inches to a mile.

Having selected a base line A B, Plate II., and conspicuous

* Some persons prefer using the lines on the paper as East and West instead of Meridians; laying a protractor which has lines engraved across it with these

PLATE II.

To face p. 34.



), E, F, G, H, K, we should go to A and observe of the different points.

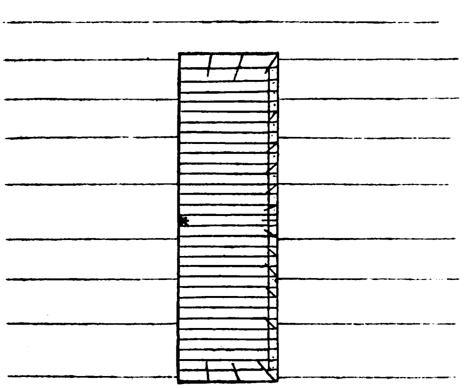
be saved by taking the bearings of two Stations ile the compass is steady, direct the vane on the y, being careful not to shake the card. They oted thus :—

At A	B	24° 30′
	C	56°
	D	102° 15′
	E	155° 45′
	F	198° 30′
	G	247°
	H	305°
	K	346° 45′

sary to consider where the work should be com- e paper, so that there may be room for the whole s A being in a central position on the ground, corresponding position in the sketch.

nciding with any on the sketch as shown, when the edges will th. Probably the original intention of this arrangement was to y of closely-ruled meridians on the sketch.

N



S

The Protractor is adjusted at this point as explained, and with the graduated edge to the right; dot off the angles under 180°, viz., B 24° 30′, C 56°, D 102°, E 155° 45′, denoting each angle by its distinctive letter. (Plate II.)

Next lay the protractor with its graduated edge to the left and mark the direction of the bearings over 180° to F, G, H, and K.

Draw fine lines of indefinite length, through these points.

The length of the base A B is next measured by pacing or otherwise, and found to be 679 yards, this being laid off to scale 6 in. to M., fixes the point B.

The bearings of the Stations from B are observed—

At B	C	103°
	D	149° 30′
	A	204° 30′
	H	257° 30′
	K	293° 30′

Adjust the protractor as before, with the centre at B, and mark the direction of these observations. These lines produced till they intersect the relative lines drawn from A determine the position of Stations C, D, H, K. Or (in order to avoid placing unnecessary lines on the paper) merely mark the position of the point of intersection without drawing the whole line.

Next, the Stations D, E, and H are visited, and the following observations made and laid down.

At D	C	358° 30′
	E	213° 15′
At E	F	264°
	G	296°
At H	F	164° 30′

This last observation is taken as the angular test; if the triangulation is correct, the line H F, when laid down on paper, will pass through the point F already fixed by bearings from A and E.

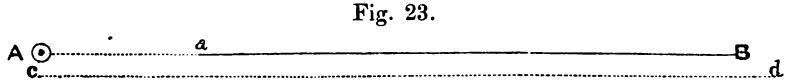
It is important that the name or letter denoting the Station should be at once marked on the line drawn towards it, else there will be confusion and errors as to the point of intersection when there are a number of Stations.

Each Station is surrounded with a small circle, and no lines are produced within this, so that the exact position of the point may be preserved.

It frequently happens that, in hurried work, accidents of the ground interfere with our view of Stations from the point of observation; when this is the case, we may still obtain the observation with the compass by a little management with greater facility than with any other instrument.

The bearing of a line will evidently be the same at all points *on* that line.

Fig. 23.



If, then, finding that station B is concealed from A (the point of observation), we may walk towards B until we reach a point *a* whence the bearing can be taken.

Or we may find it more convenient to get a little on one side of A and observe the bearing of the line *c*, *d*, parallel to A B. Either of these will be the same bearing as if observed *at* A.

If working alone, the surveyor may align himself between A and B by laying a straight walking-stick on the ground and observing its direction with regard to A and B from each end, shifting its position right or left until he finds that it will coincide with that line.

If two persons are working together they may quickly align themselves between two distant points by facing each other at about 20 yards distance apart, each dressing the other on a point, and both moving to the right or left as may be required, until each masks the distant point from the other.

INTERPOLATION.

It will be remarked that the bearing of a line observed with the compass at one end, will be the opposite degree of the circle to the observation at the other end.

If standing South of an object its bearing will be 360°, or North, and the bearing of the spot at which we are standing, *if observed from that object*, would be 180°. In the same way, 90° and 270°, or 282° and 102°, &c., are the reciprocal bearings of objects. This enables us to find the position on paper of any point at which we may be, when two fixed Stations are visible.

Suppose, for instance, that we wish to find the position on paper of D. Fig. 24. We take the bearing of two Stations A and B previously fixed

to A 282° 15′, to B 329° 30′,

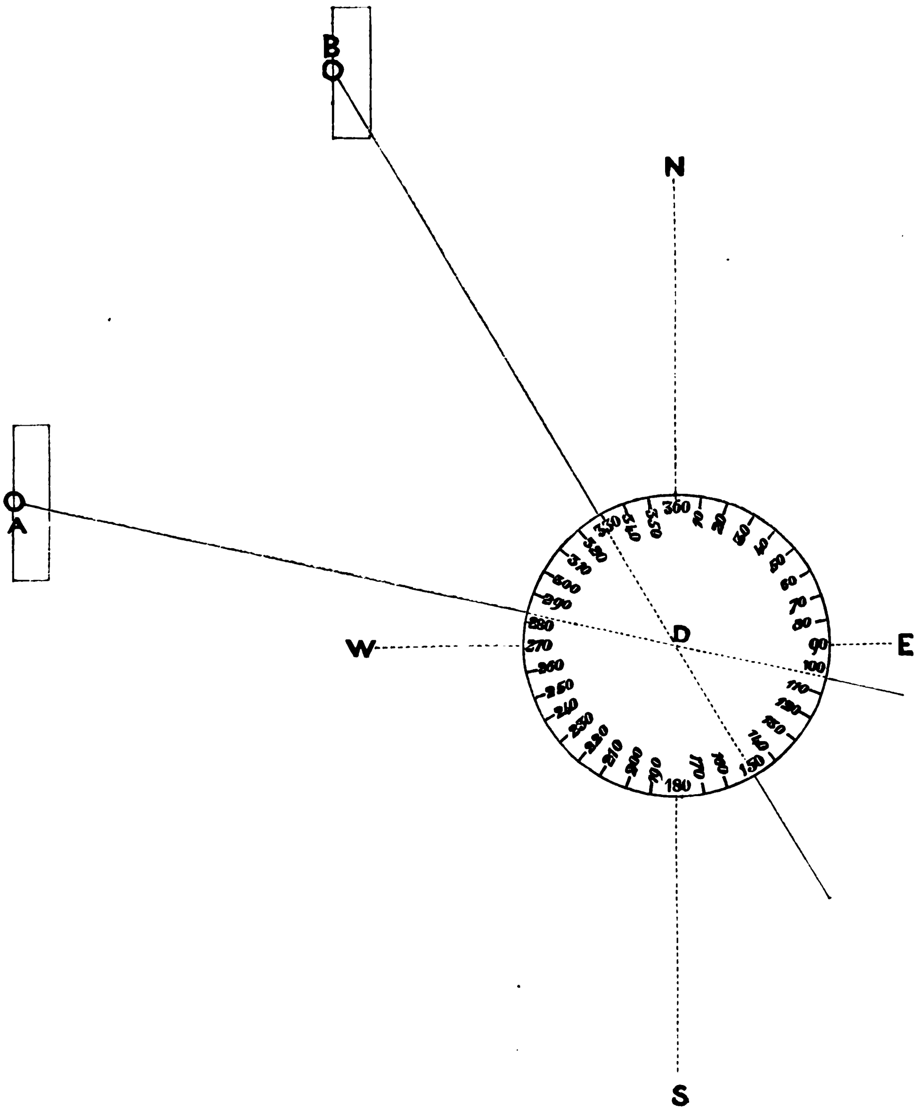
and lay down the opposite degrees

from A 102° 15′, *from B* 149° 30′.

Each degree on the ivory protractor being numbered with the opposite degree corresponding on an inner line the required angle is at once known. Or merely reverse the ordinary method of protracting the angle, *i.e.*, lay off bearings under 180° to the left, over 180° to the right.

This will be found a most useful operation in every branch of sketching; for instance, Stations may thus be determined in the triangulation, the accuracy of the work at any time may be checked, or the position of a cross road or other favourable starting point may be found.

Fig. 24.



In order to find the position accurately by interpolation it is necessary that there should be a good intersection at the required point, and therefore the two Stations observed must be selected with that view. We may observe three or four Stations if we wish further to verify the position.

MAGNETIC VARIATION.

The direction of the true North should always be shown on a sketch.

In a combined survey performed by several persons, the chances are that no two of their compasses point to the same magnetic North. But in order to join the sketches correctly, one line, (the true North) must exist on each, common to all.

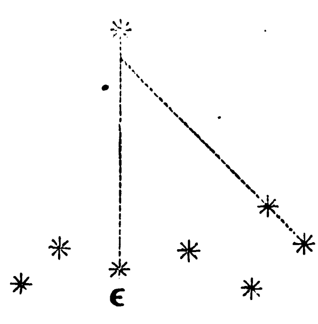
The variation of a compass is its deviation from the true North.

This differs at various parts of the globe; in the South of England, at present, the variation is about 19° 32′ West of the true North. In the Northern part of India about 2° East.

Every person should ascertain the variation of his compass, when he can lay down the true North by drawing a line making an angle with the magnetic meridians on his sketch equal to the amount of variation.

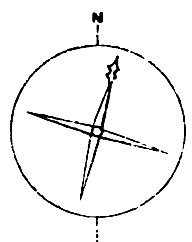
When the star ε of the Great Bear is vertically either above or below the Pole Star (as is the case twice in the 24 hours), find by a plumb line a well defined distant object in the same plane.

Fig. 25.

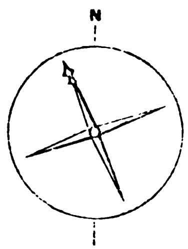


Take the bearing of this object by daylight. If this be, for instance, 347° 30′, it shows that the compass points 12° 30′ to the East of true North.

Fig. 26.



Magnetic Variation 12° 30′ E.



Magnetic Variation 25° 15′ W.

If 25° 15, the compass points that number of degrees West of true North.*

To lay down the meridian on a sketch.

Having observed the bearing of a side of a triangle, or of one known point from another, adjust the protractor with its centre at the point of observation, and the observed degree coinciding with the corresponding line on the sketch, the edges are N. and S.

QUESTIONS FOR PRACTICE.

In Fig. 16. The bearing of F from B being 311°, and the magnetic variation of the compass 15° W, lay down the magnetic and the true North.

In Fig. 15. The bearing of F. from A is 62°, and the magnetic variation 20° E.

* The above method is so simple that it would be unnecessary to commit any other to memory. The true North may also be found by the sun, if a Nautical Almanac is at hand giving the "Equation of time," the number of minutes before or after noon on which the sun is on the meridian. The true local time must also be known.

SECTION V.

TRAVERSING WITH THE PRISMATIC COMPASS AND FIELD BOOK.—PLOTTING.

Having completed the triangulation, the next step will be to traverse the roads, boundaries, &c., and either fill them in on the sketch at the time, as is usually done in small surveys; or else record the measurements in a Field Book, from which notes the survey may subsequently be plotted at leisure.

This latter system is adopted when the survey is on a large scale, or great accuracy required, or where a permanent detailed record of the measurements is desirable, and it is to be recommended as a good preparation for field sketching at sight.

The Field Book has a column ruled lengthways down the centre of each page, called the chain column as it represents the chain itself on the line along which it passes in measuring, this answers to the "forward angle" in sketching.

The only entries made in this column are *the forward measurements and their direction.*

The side columns are called the right and the left offset columns; in them are entered the width of the road on each side of the chain line; the position and form of all houses, fences, &c., as we pass them; and the angles taken to objects lying off the traversed line.

An offset is a measurement taken perpendicular to the forward angle; this is one of the most important processes in surveying, and by this means the form of most objects is measured.

The order in which the entries are made in the Field Book is the reverse of the ordinary method; for we commence at the end of the last page and continue upwards and towards the beginning of the book.

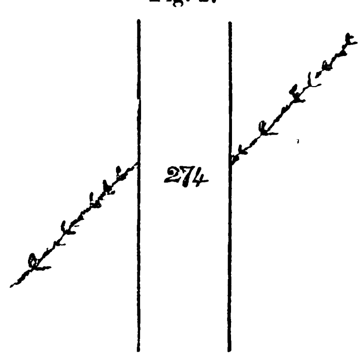
When traversing, the Field Book must be always held so that the direction of the chain column coincides with that in which we are going; then no mistakes can occur in entering the details on the right and left in their respective offset columns.

Each entry must have a separate line devoted to it, and the offset entries must be made on the same line as the forward distance in the chain column opposite which they occur.

The position and true form of all objects is denoted in the offset columns *entirely by the figures* recording the measurements taken, and no object need here be drawn to any particular scale: conventional signs somewhat explanatory of their forms are entered, and we usually exaggerate the peculiarities of shape of houses, irregular fences, &c., in the offset columns, in order to convey a clear idea of the particular measurements to which the accompanying figures refer.

We must bear in mind that the chain column represents a line having no breadth, and therefore no representation of the sides of the road or any other detail must be made in it; if, in traversing, we cross a road or fence obliquely, it must not be represented in the Field Book as passing obliquely across the chain column, but must arrive at one side of the column and leave it at the other at points precisely opposite; as would be the case were the chain column of the thickness of a line, thus:—

Fig. 27.



All the figures entered refer either to linear measurements or to their direction; we must be careful, therefore, to distinguish between these by attaching the signs of degrees and minutes to the latter, so that they may not be mistaken for linear measurements. Some persons use a red pencil to enter the angles, and a black for the distances.

It is important that the entries should be clearly and legibly written: if a mistake occurs, a line should be drawn through it, and a fresh entry made.

TRAVERSING.

The scale at which the work is to be plotted must be borne in mind when traversing. It would be useless to make measurements of objects which could not be shown in plan, and therefore the frequency of measurements, and the size of objects worth noticing will depend on this consideration. The smaller the scale the less minute the measurements.

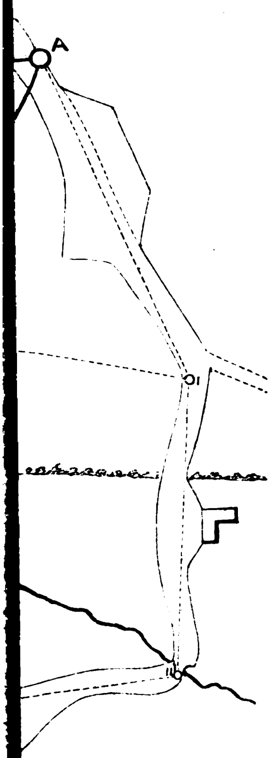
The different points at which fresh forward angles are observed, are denoted in the Field Book by the sign ⊙. A line is drawn across the chain column at the end of each forward angle.*

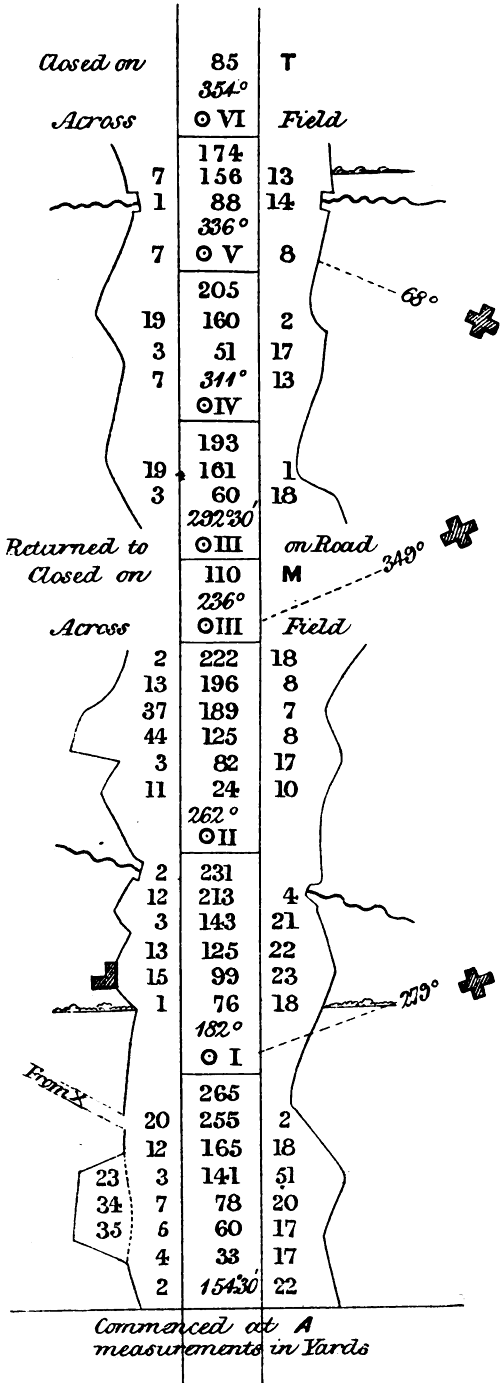
The traverse is commenced at A ; a conspicuous object in the distance is selected, giving the line of direction towards ⊙ I., the bearing 154° 30′ of this forward angle is the first entry in the chain column.

Offsets perpendicular to the forward angle are paced, the fences of the road being 22 yards on the right and 2 on the left. Before leaving the forward angle to pace an offset, a mark should be left at the spot so that the pacing may be resumed there.

* The whole of the Triangulation is not shown in the Plate, but only the Stations A, T, and M, which are used for starting and closing Stations.

To face p. 44.





d line.

We then measure forwards in a direct line towards ⊙ I.,* at 33 yards distance we are opposite the corner of an enclosure on the left, and take an offset to it 4 yards.

At 60 yards we measure an offset to the edge of the road (5 yards) and to the angle in the enclosure (35 yards), both on the left. Observe that all measurements are inclusive, and that when offsets are measured to two or more objects on the same side, they are all counted from the point where we leave the forward angle.

⊙ I. is 265 yards from the starting point, and we draw a line across the chain column at the end of this measurement.

Take the bearing of some distant object for the next forward angle, giving the direction of the longest view down the road towards II.

Observe also, and enter in the right offset column, the bearing of the church steeple.

We then measure forward to ⊙ II., taking such offsets as seem necessary (shown in the Field Book).

A careful examination of the Field Book and the sketch simultaneously, will explain the method in which the remaining entries are made. At ⊙ III. and at ⊙ V. the church spire is again intersected; this system of intersecting important objects which are too distant to be found by offsets in traversing, will be found most useful; more especially when there are no regularly triangulated Stations. We not only thereby determine the position of such points, but also obtain a means of checking the accuracy of the work; for the angles taken from three or more ⊙ s to the same point, will (if the work be correct) converge at that point on the plan.

* The accuracy of all the offset measurements depends on the preservation of the true line from ⊙ to ⊙ in pacing forward; this is a particular in which almost all beginners fail. The true line is preserved by observing either some intermediate or some distant mark which is exactly in the same line as the forward ⊙, and keeping these two points dressed whilst advancing.

The necessity of having a good angle at the point of intersection must again be considered in this operation, and the distance between the points of observation will therefore be proportionate to the distance of the object.

We should make as much use as possible of the triangulation, and avail ourselves of every opportunity of checking the work by starting afresh from Stations and working up to and "closing on" other Stations, by so doing we divide it into a series of separate operations, and confine any errors within narrow limits. If the work be incorrect in any part we at once detect the locality of the error when laying it down on the plan, and such error will not affect any part of the operation save that between the immediate starting and closing Stations.

PLOTTING.

The process of laying down in plan the work entered in the Field Book, is termed "plotting."

When the ivory protractor is used, it is adjusted by the meridian lines N. and S., and with its centre at the starting point.

First, lay down each forward angle in succession and the *total distance from* ⊙ *to* ⊙ without regarding the intermediate entries; when there is a triangulation, we by this means ascertain that the plotting "closes" satisfactorily, before proceeding with minor detail.

Next. Return to the offsets. Measure the forward distances, as entered in the chain column, from each ⊙, and lay off the corresponding offsets perpendicular to the forward angle. The position of the sides of the road being thus marked here and there, these points may be joined in the first place by straight lines, and afterwards joined with the requisite amount of curve.

It must be borne in the mind that the measurements, both forward and offset, are inclusive.

The position of the paper should be shifted as required, so that the direction of the forward angle may correspond with that of the chain column of the Field Book laid upon it, else there would be a tendency to reverse the position of the offsets.

The ⊙ s are numbered corresponding with the Field Book. The forward angles are sometimes drawn in colour, and the plan is finished up in Indian ink, after being correctly pencilled in.

Houses should be drawn with a mathematical pen and ruler, not freehand.

SECTION VI.

SKETCHING ROADS, ETC.

The kind of sketching required usually for military purposes does not necessitate a high degree of accuracy the instruments being the prismatic compass and the ivory protractor, and the two processes of traversing and plotting being carried on in the field simultaneously; the most difficult part of sketching, viz., the representation of hills, must be reserved for after consideration.

If the reader has practised the method of traversing and plotting from the Field Book, he will find no difficulty in sketching at sight.

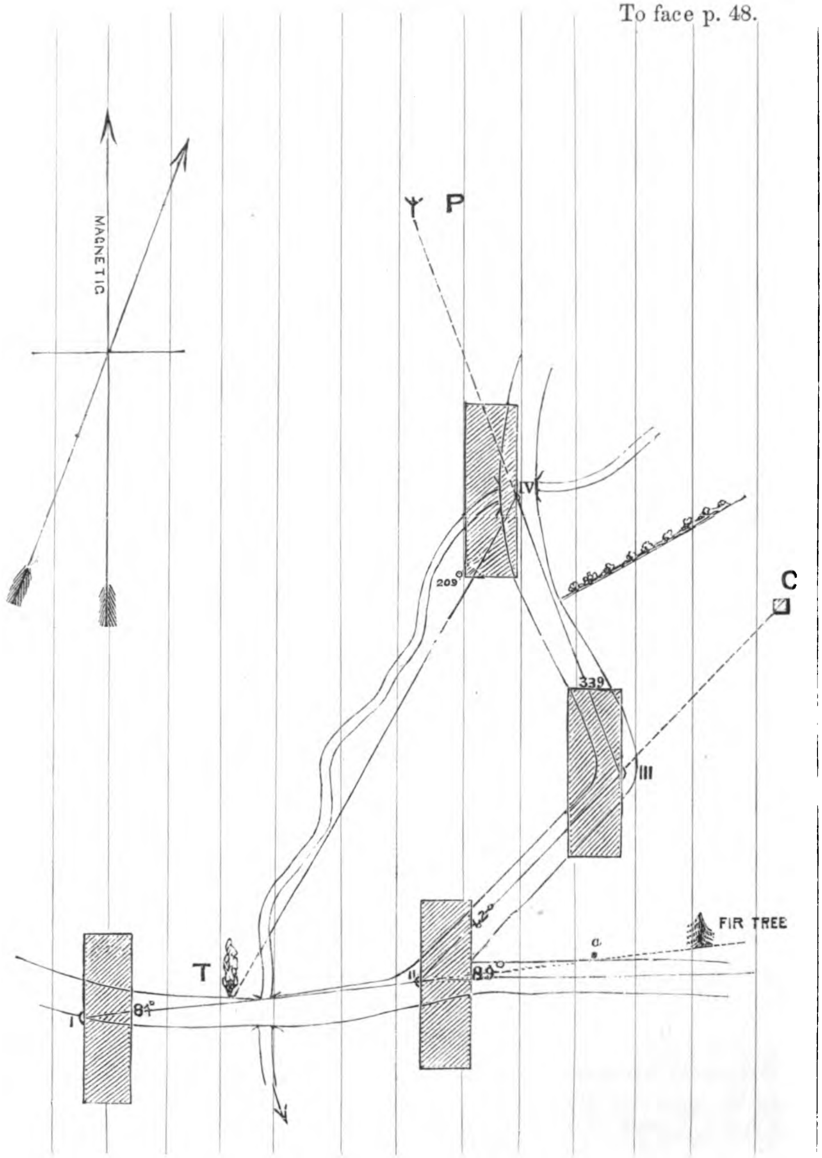
The sketching paper is prepared with parallel lines which may be used either as Meridians or as East and West lines as described. (Page 34).

This is held in a sketching case which is usually provided with a strap to pass round the surveyor's neck, whilst a loop fastened to one of his buttons, forms it into a sort of table. This, though apparently a convenient arrangement, must be condemned; as a beginner will certainly be unable to realize the relation of his sketch to the ground, unless he carries it in his hand and holds it in a position corresponding with the direction in which he is going. If he accustoms himself to do thus, it will greatly simplify the work.*

* The fault of most sketching cases is that they are too small. Nothing is more provoking than to find oneself going off one's paper in surveying. I recommend as preferable to the leather cases generally used, a board of seasoned deal, not

PLATE IV.

To face p. 48.



Scale 30 inches to a Mile.

It may be well first to explain, step by step, the manner in which a sketch of this nature on a large scale was executed, though in doing so, much of what has been said has to be repeated.

The sketch being drawn on the scale of 30 inches to a mile, the scale of 6 inches to a mile engraved on the protractor was used, and each measurement multiplied by 5 (Page 6).

Commencing at ⊙ I., we noticed a distant fir tree nearly in the continuation of the direction of the road giving a suitable point to march upon—observed the bearing 84°. Assumed a point on the sketch for the starting point ⊙ I., adjusted the protractor, its centre at this point, its edges parallel to the meridian lines and the graduated edge to the right; marked the position of 84° and drew a light line indefinitely in that direction.

Paced the width of the road (10 yards to the left) and dotted off that measurement perpendicular to the forward angle.

Returned to the starting point and looked out for some object, either intermediate or distant, on the same line as the fir-tree (Note, page 43), selected a bush in the hedge-row at *a*, and kept these two objects aligned whilst pacing forwards.

At 55 yards we reached the commencement of a stone bridge, the line of direction having brought us close to its left side. Marked this point on the sketch and paced the width of the bridge 8 yards, joined these points to the sides of the roads marked at the starting point.

Continued the forward measurement towards the fir-tree,

smaller than 11 by 14 inches, about one-fifth of an inch thick, strengthened by three slips of hard wood across the grain at the back. Lay this face downwards on two or three sheets of sketching paper about an inch larger than it, cut off the corners of the paper to fit the board, turn down the edges to the back, and fasten them down with thin slips of wood screwed or clamped in any convenient way over them. When a fresh sketch is undertaken, run a penknife round underneath the old one.

A waterproof case in which to carry it, should be provided.

recommencing the counting at 55. Sixty yards brought us to the far side of the bridge; at 80 yards we began to leave the left side of the road which was now 2 yards off. Noticing that the road continued of the same width 10 yards, we sketched in the remainder with regard to its position to the line of direction, without pacing more offsets.

At 105 yards we reached a cross road, at a spot whence we could command a good view down each road; halted here, and took the bearing of each 42° and 89°. The forward angle 42° was taken on a cottage chimney C, a stone on the road serving as an intermediate point of alignment.

Pacing forwards, the line of direction kept the middle of the road for 90 yards, so we sketched the sides in at 5 yards on each side.

Here a fresh forward angle had to be observed to a distant post P, 339°, laid off to the left, &c.

Wishing to sketch the stream from ⊙ IV., we observed the bearing of a poplar tree T, which seemed to be somewhat in the direction of its course 209° and paced on it, estimating here and there the distance of the stream as its position altered; this we were able to do with sufficient accuracy as the distance was at no part greater than 10 yards.

After following the stream for 180 yards we reached the side of the road near the starting place, and as this distance corresponded nearly with the measurement on the sketch, the correctness of the work was proved.

The forward angles should be drawn lightly, as they do not remain permanently on the sketch.

If the distance between the starting and closing Station be great, it may be well to check the work by interpolation (Page 36) occasionally; a bearing to even only one Station is some check on the correctness of the distance traversed.

SECTION VII.

REPRESENTATION OF THE FEATURES OF THE GROUND.

The sketch being finished so far as to show the roads, fences, and other detail, we now come to the representation of the hills and undulations of the ground, which, in a tactical point of view, are of the utmost importance.

This part of military surveying gives the greatest scope for the display of individual intelligence and quickness.

Hills must be represented in such a manner as to convey a striking and, at the same time, true and unexaggerated idea of the form of the various features, their slope or inclination to the horizon and their relative altitudes; in fact, there must be combined in the plan the information which would be conveyed both by a vertical and a horizontal view of the ground.

These conditions being unnatural, a conventional style of delineation has to be adopted.

The earliest manner of representing hills seems to have been by a sort of bird's-eye view. This style undoubtedly has the advantage of appealing in an unequalled degree to the understanding of persons uneducated to read military plans, and as such, is still to some extent adopted in the "maps of the seat of war" published for the million. It is, however, quite insufficient for the requirements of a military sketch, as it merely conveys the idea of the existence of a hill in a certain locality, without defining its entire form, only the near side of the hills being visible.

Later on, hills were depicted as occupying their proper area on the map, the idea of relief being obtained on the supposition that the observer viewed them from a point vertically over every point on the ground; so that the eminences would appear distinct and well defined, whilst the valleys and low ground would be affected by atmospheric perspective, and would be subdued and blended. Thus, the body of shade and the high light was distributed about the summits, and the valleys were kept dim and faint.

This system gives a capital effect of relief to the sketch, and enables us to show the relative altitudes fairly. On the other hand, it conveys an entirely false idea of the form of the slopes, which appear uniformly concave, it is also ill adapted for military sketches as showing least distinctly the most important tactical features, the low ground and manœuvring slopes, under 15° or so.

For the effectual representation of some kinds of ground (particularly mountains), it is difficult to dispense altogether with a modification of this arrangement of shade.

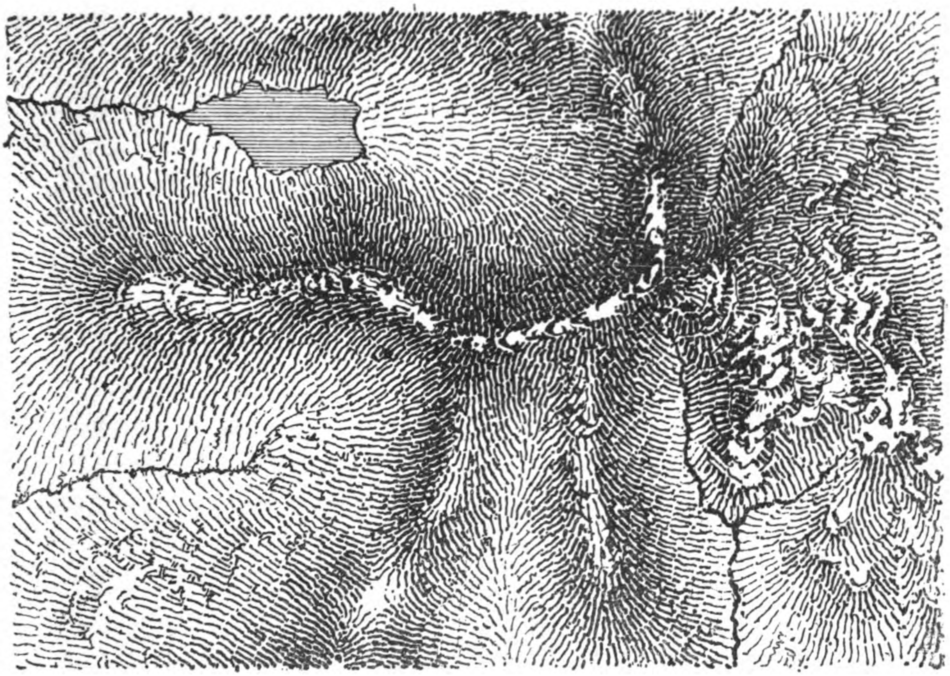
In the upper example, the vertical style of drawing is represented, wherein every touch or hâchure is drawn orthogonally to the contours, or in the direction of the fall of the ground.

The same distribution of shade might be made on the horizontal system, in which each hâchure coincides with the contour, as shown in the lower example.

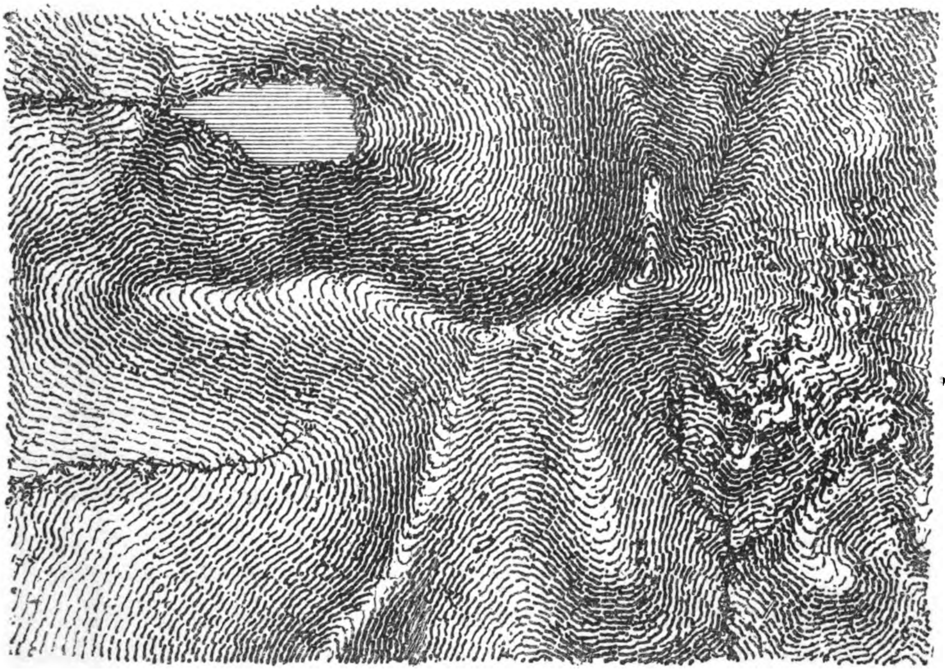
Excellent effects of relief are produced in brushwork with little labour, but being inapplicable to field work, it is now little employed.

The effect produced by the Anaglyptograph process on the principle of oblique illumination is very striking, good specimens of this style may be seen in Siborne's maps of the battle fields of 1815.

In the present system a definite amount of shade is allotted to certain slopes without reference to their relative altitudes, these being shown either by figures or by the *contours*.



Vertical Style of Drawing.



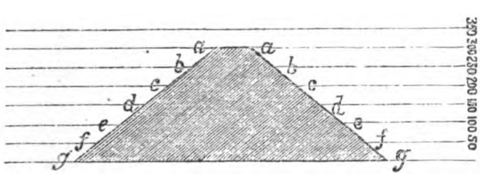
Horizontal Style of Drawing.

A contour is the line of intersection of a hill by a horizontal plane.

For example, the line defined by the edge of the sea is a contour, and on a coast where the tide rises and falls 30 feet, seven contours might be marked at 5 feet vertical intervals, by tracing this line at every 5 feet difference of level of the tide. These lines, surveyed and drawn to scale, would be a *contour plan* of that ground.

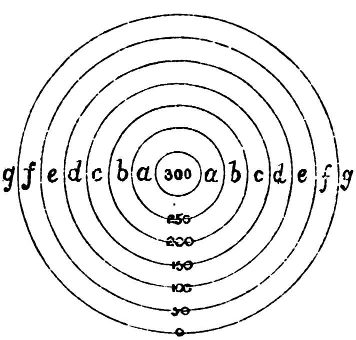
Suppose a hill to be of the form of a truncated cone (Fig. 28), and the vertical distance between the horizontal planes *a*, *b*, *c*, &c., by which it is intersected to be 50 feet, the

Fig. 28.



Elevation.

Fig. 29.



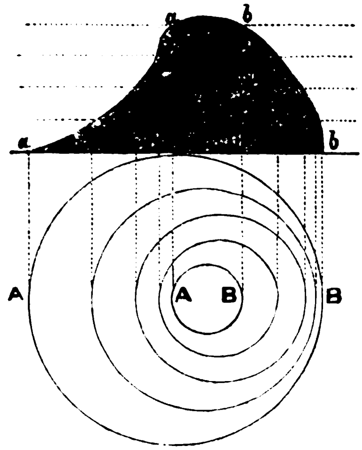
Plan.

contour plan of the same (Fig. 29) will show the height of the hill 300 feet, or the altitude of any part of it.

Besides the relative altitudes, the contours explain the form and flexure of every slope. A A and B B (Fig. 30) show the exact concavity and convexity of the slopes *a a* and *b b*, as the contours will occur in smaller horizontal distances in proportion to the steepness of the ground.

The opinion seems gaining ground among military men that if the operator has skill enough to sketch suitable ground by contours, as hereafter described, shading is superfluous;

Fig. 30.



for though giving the sketch a more finished appearance, it does not make it more expressive to an officer trained to read contoured plans.

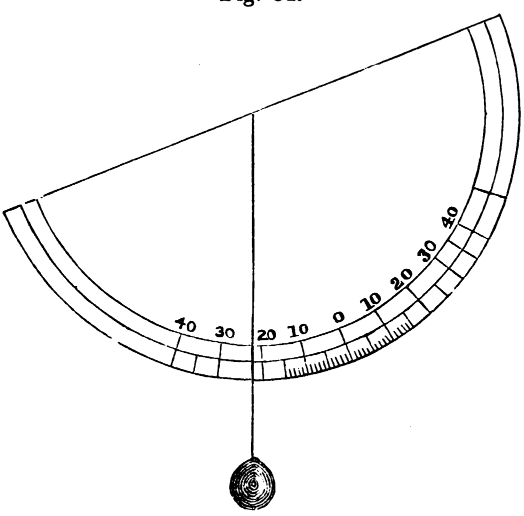
SECTION VIII.

CONTOURING WITH THE CLINOMETER.

In the present system the clinometer is employed to find the position of contours in hill sketching; by its assistance the process is rendered to a certain extent mechanical.

This may be made on a quadrant or a semicircle of stout cardboard (about twice the size of the figure), its edge being graduated from a centre, from which a plummet is hung.

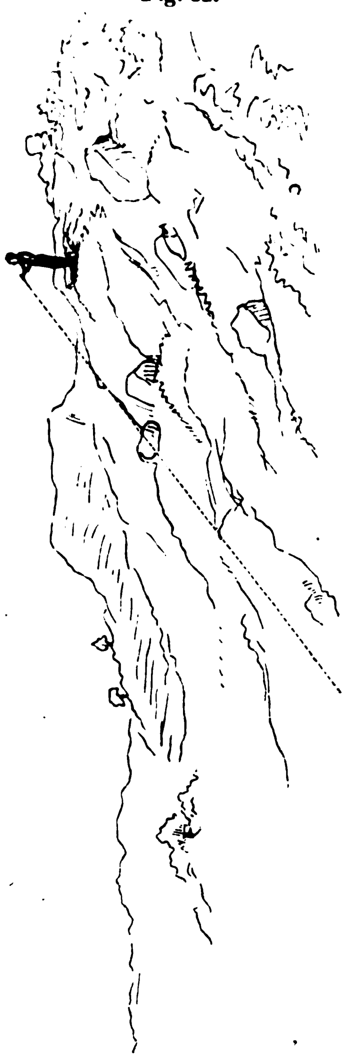
Fig. 31.



The zero is placed perpendicular to the diameter, so that when the clinometer is held with the plumb line coinciding with O a level line can be observed by looking along the edge.

To observe the slope or declination from the horizontal plane. The clinometer is held with both hands at some distance from the eye, with the diameter parallel to the surface of the ground, when the plumb line indicates the elevation or depression in degrees.*

Fig. 32.



If the slope of the hill *a* B Plate VI. (I.) be observed 2° we can calculate in what horizontal distance any required vertical interval (or difference of level) will occur.

Suppose the vertical interval be 18·75 feet In the triangle *a b c* Plate VI. (I.) the cotangent *a c* will be 179 yards.

Then points *b*, *d*, *e*, *f*, may be marked on the sketch, representing each a difference of level of 18·75 feet for the distance in which the slope continues to be 2°. Plate VI. (II.).

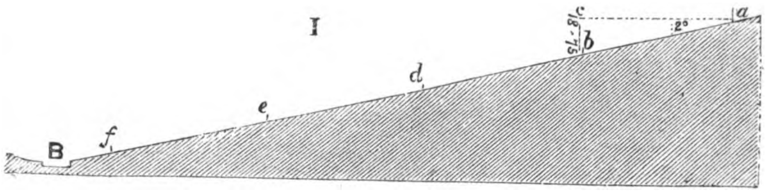
If from the same point *a* the slope in the direction of C, Plate VI. (II.) be observed to be uniformly 4°, the horizontal distance in which 18·75 feet vertical will occur, will be 89 yards; and as many repetitions

* The surveying protractor is sometimes used as a clinometer, a pellet being hung from the centre; but it cannot be depended on for the measurement of gentle slopes, the length of radius being only about 1½ inches.

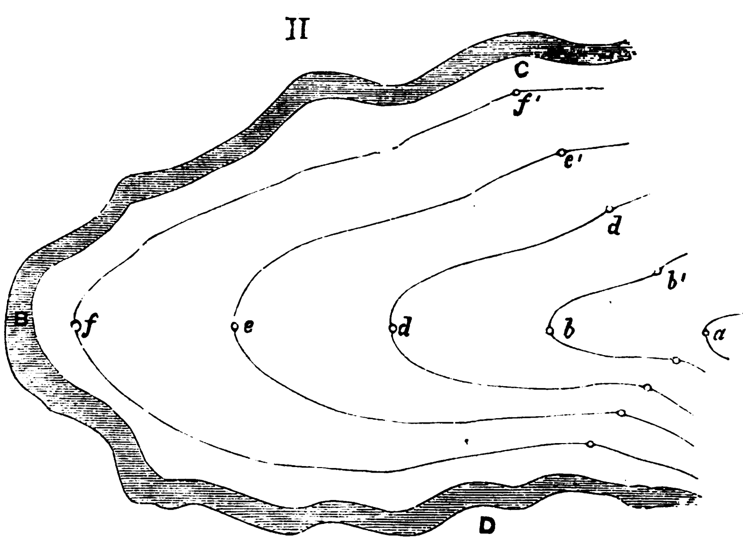
There are several patterns of clinometers intended to be used as protractors

PLATE VI.

To face p. 58.



Section on *a* B, heights to distances 6 to 1.



Scale 8 in. to M.; contours 18·75 ft.

of this distance as *a* C, Plate VI. (II.) will contain, may be marked off on the sketch, viz., b', d', e', f'

In the same manner, if the slope towards D be observed 8°, the horizontal distance between the contours will be 45 yards.

The contours may then be joined through the points as shown, according to the form of the ground.

The calculations mentioned are of course not carried out in the field, all this is prepared beforehand.

For this purpose a table is first prepared, showing the horizontal equivalents for the required vertical interval at each degree of slope up to about 30° which may be written on the clinometer for easy reference, as shown below.

If it be remembered that the Horizontal Equivalent for *one foot at one degree of slope is* 19·1 *yards nearly*, that for any conditions may be easily calculated with sufficient accuracy.

If, for instance, the required vertical interval be 25 feet, the horizontal equivalent at 1° is 19·1 × 25 = 477·5 yards.

$$\text{Then, at } 2°, \frac{477·5}{2} = 239 \text{ yards.}$$

$$3°, \frac{477·5}{3} = 159 \text{ yards, \&c.*}$$

TABLE OF HORIZONTAL EQUIVALENTS FOR 25′ CONTOUR.

Yds.	Yds.	Yds.	Yds.	Yds.	Yds.
1° = 477	5° = 95	9° = 53	13° = 37	17° = 28	21° = 23
2° = 239	6° = 79	10° = 48	14° = 34	18° = 26	22° = 21
3° = 159	7° = 68	11° = 43	15° = 32	19° = 25	25° = 19
4° = 119	8° = 60	12° = 40	16° = 30	20° = 24	30° = 16

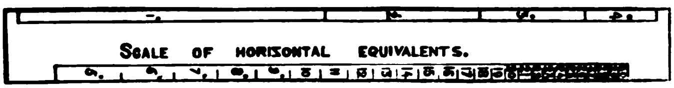
Next, in order to save the trouble of laying off these distances on the sketch from a scale of yards. A scale of horizontal equivalents is prepared on the edge of a card or the

also, and having the scale of shade, horizontal equivalents, &c., but they are generally of an inconvenient shape for use as protractors. As the scale of shade is not required in the field, and the clinometer can be dispensed with after a little practice, it is as well to keep the two separate.

* This method is practically correct, though not theoretically so, for the difference up to 30° between the table thus calculated and the true cotangents is less than unity in yards, and therefore inappreciable.

back of the clinometer. The above table laid down at the scale of 6 inches to a mile produces this scale.

Fig. 33.



These conditions have been assumed because sketches of positions are generally made at the scale of 6 inches to a mile, at which scale 25 ft. contours, produce horizontal equivalents suitable for representing ordinary ground.

This scale of Horizontal Equivalents (Fig. 33) is under the present system used in the field for all tactical sketches.* When the plan scale is other than 6 inches to a mile, the conditions which it expresses vary in proportion.

For instance, contours placed at this distance apart *on any sketch* will represent a slope of 2°.

If the scale be 6 inches to M., these distances are, as we have seen, 239 yards. Now if the scale were 12 inches to M. the same distances in plan will, of course, represent only one half, or 119 yards.

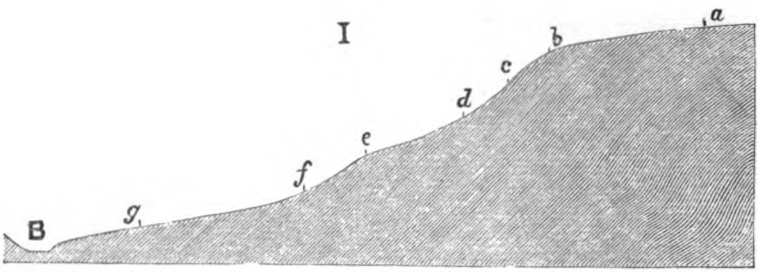
Similarly, the Horizontal Equivalents for 3°, which on the scale of 6 inches to a mile measure 159 yards, will measure on 12 inches to a mile one half or 79 yards; 4° will be 60 yards, &c.

* This system of employing but one scale of Horizontal Equivalents greatly simplifies the reading of sketches, the eye soon gets accustomed to recognize the slopes they represent and to take in the manœuvring capabilities of the position, which could not be the case were different Horizontal Equivalents used.

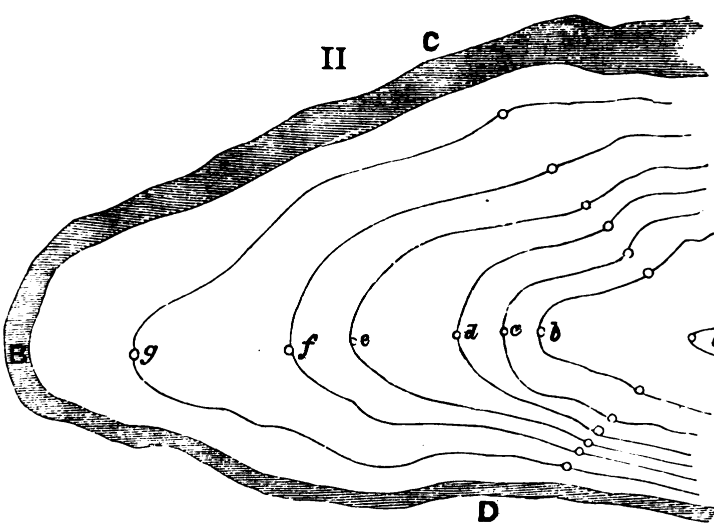
For reading contoured maps drawn on a different system from that above described a scale of Horizontal Equivalents suitable to the vertical interval and plan scale may be constructed in the same manner.

PLATE VII.

To face p. 63.



Section on *a* B, heights to distances 6 to 1.



Scale 12 inches to a Mile. Contours 12·5 feet.

Then the vertical interval represented by the same Horizontal Equivalents will vary in like proportion, as but half the difference of level (vertical interval) will occur in half the distance at the same slope; the vertical interval, therefore, in this case will be 12·5 feet, or half that expressed when the scale is 6 inches to a mile.

The vertical interval to be adopted is found by proportion, if the scale be 9 inches to a mile

$$9'' : 6'' :: 25 : 16{\cdot}66' \text{ vertical interval.}$$

Or suppose the representative fraction be given $\frac{1}{15840}$.

That of 6 inches to a mile being $\frac{1}{10560}$

$$10560 : 15840 :: 25 : 37{\cdot}5 \text{ feet vertical interval.}$$

If it were usual for the slope of hills to continue constant for a considerable distance as in Plate VI. (I.), the process of contouring as described would be very simple. But as the slopes, as a rule, vary constantly the Horizontal Equivalents will be distributed in order following the undulations.

Plate VII. being drawn at the scale of 12 inches to a mile, the scale of Horizontal Equivalents expresses these conditions.

$$12'' : 6'' :: 25' = 12{\cdot}5 \text{ feet vertical interval.}$$

$$\text{Then } 1^\circ = 19{\cdot}1 \times 12{\cdot}5 = 239 \text{ yards, horizontal equivalent.}$$

$$2^\circ = \frac{239}{2} = 119 \text{ yards, \&c.}$$

Table of Horizontal Equivalents for 12·5 Feet.

yds.	yds.	yds.	yds.	yds.	yds.
2° = 119	6° = 40	10° = 24	14° = 17	18° = 13	24° = 10
3° = 80	7° = 34	11° = 22	15° = 16	19° = 12	26° = 9
4° = 60	8° = 30	12° = 20	16° = 15	20° = 12	28° = 8
5° = 48	9° = 26	13° = 18	17° = 14	22° = 11	30° = 8

Standing at *a*, Plate VII. (I.) the slope is observed to be 2° for some distance; mark off from the scale of Horizontal Equivalents that for 2° in the direction of B, and pace the corresponding distance 119 yards to *b*; this places us at the spot on the ground agreeing with that marked on the sketch.*

Here the slope is again observed and found to be 8°; pacing forward we find that this continues far enough to admit two contours, each 30 yards (the Horizontal Equivalent at 8°).

At *d* the slope is 3°, we lay down and pace 80 yards. At *e* the slope is 5°, distance 48 yards.

From *f* the slope continues 2° as far as the stream, and we find that the distance on the sketch will only contain one Horizontal Equivalent.

In the same manner we distribute the contours towards C in the Horizontal Equivalents successively for the observed slopes 4°, 10°, 10°, 12°, 6°, 4°.

And from *a* towards D for 4°, 7°, 15°, 20°, 20°, 20°, giving points on the same levels and same contours as *b*, *c*, *d*, *e*, *f*, *g*.

The difficulty of placing the contours increases in undulating ground, Plate VIII.

Here, commencing at A we find the first part of the slope to be 7°, lay off the Horizontal Equivalent and pace 68 yards to *b*.

From hence the slope is observed to be 12° for a considerable distance, pacing towards B we find that it continues sufficiently far to contain three Horizontal Equivalents, each 40 yards, *c*, *d*, *e*.

At *e*, judging that we have reached about the same level as

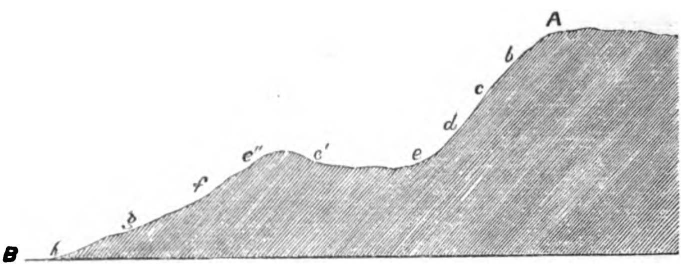
* It will be remarked that the horizontal equivalent laid down in the sketch is the base, whereas we pace the corresponding distance on the Hypothenuse or surface of the ground. The difference between the hypo. and base, however, is so trifling at low gradients that we may ignore it when the measurements are made by pacing. At so steep a slope as 15° the difference would be only 3½ yds. in every hundred, at 10° it would be only 1½ yds.

The scale of Horizontal Equivalents is only intended for *tactical sketches* (which are made at large scales).

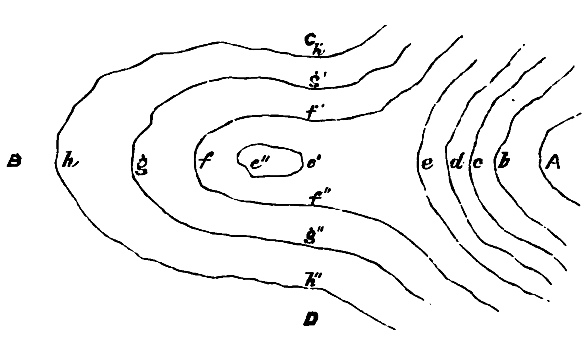
It would frequently be unsuitable for the representation of ground at small scales. At 3 inches to a mile, for instance, the contours being at a vertical interval of 50 feet, would escape many important features, or there might not be that difference of level between the highest and lowest parts of the position.

PLATE VIII.

To face p. 67.



Section on A B, heights to distances 6 to 1.



Scale 6 inches to a Mile. Contours 25 feet.

the knoll, we use the clinometer as a level, looking along the edge whilst the plumb line agrees with O. Making due allowance for the height of the eye from the ground, we find that the level at which we are standing strikes the knoll at e'. Judging that the dip between e and e' will not include another contour we pace across to this spot which is found to be 180 yards and mark that distance e' on the sketch.

Here we notice that the slope is nearly uniform for a distance that we judge to be about 200 yards on each side, towards C and D. The observed slope towards C being 9°, we mark off on the sketch as many repetitions of that Horizontal Equivalent as will fit in the distance, viz., f', g', h'. And towards D the Horizontal Equivalents for 7° fixing f'', g'', h''.

We now pace to e'', a point which we judge to be on the same level as e' distant 93 yards, and lay down this point on the sketch.

Starting afresh from here, we fix f, g, h, successively at the distances due to 7°, 5°, and 4°, and join in the contours with a due regard to the form of the ground intervening between them and the points already fixed on the same contours.

It would be impossible to lay down any one system of finding the contours which would be universally applicable, the method of operation must be suited to the formation of the ground, a matter which experience must decide.

In using the clinometer, one should be able to judge nearly how far down a concave or convex slope the required vertical interval will occur, so as to observe the degree of slope of that portion only.

An isolated feature may be contoured with some accuracy with the clinometer as described, but in some districts a difficulty will occur in finding a natural level common to the whole sketch, from which to commence the observation of the slopes, so that the contours of the features thus separately surveyed may be joined to each other with truth. The necessity for the existence of some such natural level will be felt in proportion to the greatness of the vertical interval.

If the sketch includes a coast line, a lake, or a sluggish river, we may avail ourselves of these as natural levels, and work upwards from them.

The following method is found to answer in sketching in the neighbourhood of Sandhurst.

Here we find level plateaux with well defined crest lines, furnishing a natural level which though perhaps not quite true is sufficiently so for the purpose.

After having laid down the triangulation as shown, Plate IX., the roads, canal, &c., were traversed, starting from and closing on the Stations frequently.

Next, the crest of the plateau was traversed in the manner recommended for the surveying of all irregular lines (long forward angles and perpendicular offsets). Thus, starting at C we took the bearing of a conspicuous tree for direction and traversed to *a*, judging or pacing the distance of the crest as we advanced. At *a* we took the bearing of an object in the general direction of the crest, and traversed up to *b*, sketching as we went. At *b* we took the forward angle on B, traversed up to and *closed* on it. Here we started afresh and worked round the crest until we closed on D, &c.

We next commenced the observation of the lower contours from this level crest. Thus, at *f* we found that Station F gave a suitable line of direction, and we observed the successive slopes in that direction and laid down the corresponding Horizontal Equivalents for 11°, 10°, and 6°.* Next at *h*, we

* The scale being 4 inches to a mile the vertical interval will be—

$\frac{25 \times 6}{4} = 37{\cdot}5$ feet (Page 57), and the horizontal equivalents will be

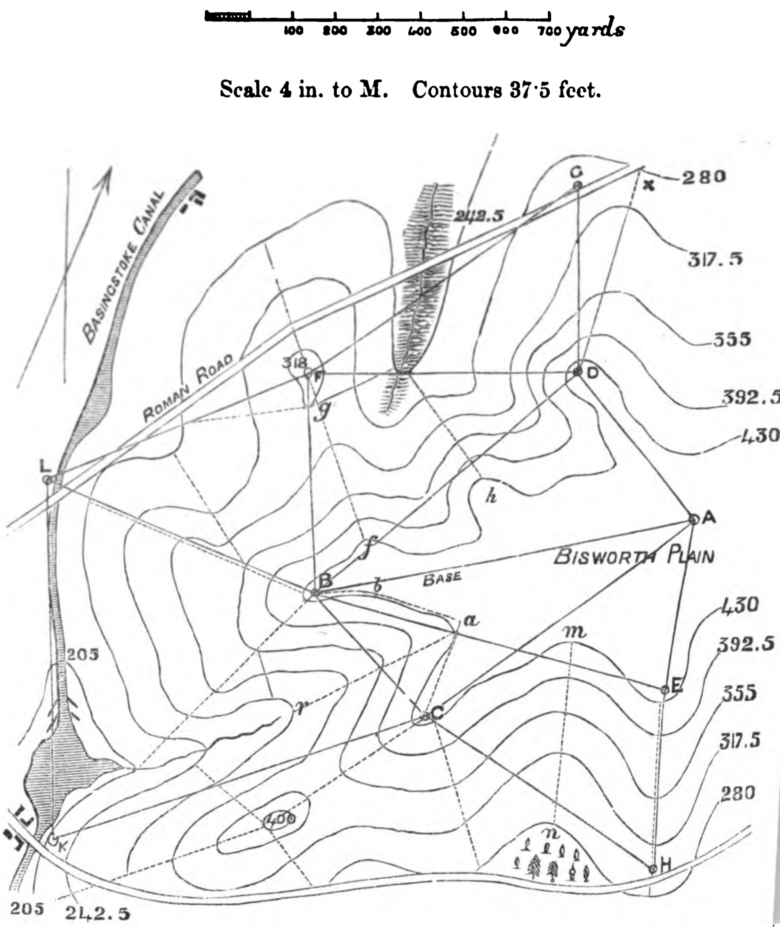
for 1°. $19{\cdot}1966 \times 37{\cdot}5 = 716$ yards (Page 55).

$2° = \frac{716}{2} = 358$ yards.

$3° = \frac{716}{3} = 235$ yards, &c.

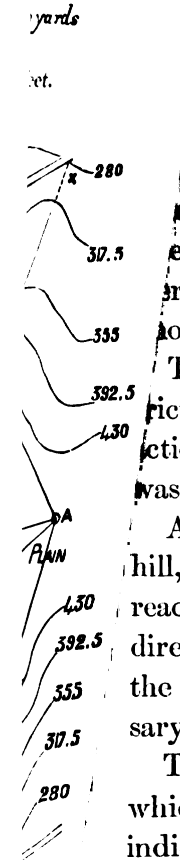
PLATE IX.

To face p. 69.



Scale 4 in. to M. Contours 37·5 feet.

To face p. 69.



ed a suitable line of direction with the compass, and g that the slope continued uniform at 12° for a distance we judged to be 300 yards we were enabled to mark once the position of as many contours as that distance l contain at 60 yards apart. We now joined these to ontours previously surveyed from *f*, having regard to the of the intervening ground.

ll the section lines (as they may be termed) on which we ked are shown dotted in the diagram, they are generally le to coincide as nearly as possible with the watershed of h underfeature,* but they must be chosen with judgment as to avoid the inconvenience of frequently observing a fresh e of direction. Whenever an opportunity occurred they re taken towards some object, the position of which was own on the sketch.

The watercourses may be joined in by eye, as in this district they have little character, being worn smooth by the action of water, and all irregularities filled in by the soil, &c., washed from the watersheds in the course of ages.

After having worked down a section line to the foot of a hill, it might seem advisable to start from the lowest contour reached and work upwards in the same manner in a fresh direction to the crest again. In some cases this may be done, but the uncertainty of the whole process renders it generally necessary to recommence at the orginal level as frequently as possible.

There will probably be many minor features of the ground which will not be shown by the contours; these should be indicated by a little sketching or by intermediate contours.

By means of the clinometer we may ascertain approximately the relative altitudes of important points the position of which is known on the sketch, and when time will not admit of representing the ground by contours these altitudes may be figured.

* This term is employed at the Military College to express the small knolls and undulations which are peculiar to that neighbourhood in the low ground.

Thus, supposing Bisworth Plain to have been only roughly sketched, the roads, &c., and the crest, only being completed. Standing at C, the angle of depression of K being observed with the clinometer would be found 5°, and on applying the scale of Horizontal Equivalents to the line C K we find that it will contain six contours, whence K is $37{\cdot}5 \times 6 = 225$ feet below C. Again, the angle of depression of F from B being found 4°, and three Horizontal Equivalents for this slope being contained in the distance on the sketch gives F a difference of level of $37{\cdot}5 \times 3 = 112{\cdot}5$ feet below B. Several points being determined in this manner, their height in feet either above or below the point of observation may be marked on them in the sketch.

After some practice in contouring and general sketching, one may obtain such an appreciation of slopes and knowledge of the horizontal position of the contours both in plan and on the ground as to be able to sketch easy country in contours by eye within 5 to 10 per cent. of truth (at any rate, with accuracy sufficient for tactical purposes), as rapidly as could be done on the old system by shading.

An experienced surveyor will combine the operations of planimetry and hill sketching, so that he need not visit the same spot twice.

The system described is only applicable to ground of which the features are tolerably rounded and smooth. It could not be carried out in rugged and broken ground; if contours be required in this case, the surveyor will when in the field survey the leading features such as the watersheds and water-courses will indicate by a few touches abrupt declivities, &c., take notice of and figure the amount of slopes, and ascertain the difference of level between important points as explained above.

His experience and judgment may then enable him, when finishing it up, or making his fair copy, to represent the contours with some truth.

QUESTIONS FOR PRACTICE.

1. What is the vertical interval between the contours of a sketch done on the present system at the scale of 5 inches to a mile ?

2. At the scale of 11 inches to a mile ?

3. When the R F is $\frac{1}{23000}$?

4. When the R F is $\frac{1}{8640 \cdot 5}$?

5. What is the Horizontal equivalent for 15 feet vertical at a slope of 8°.

6. Referring to Fig. 15. Supposing this to be laid down at 8 inches to a mile, and the following observations made with the clinometer at B.

Angle of elevation of H, 5°
Angle of elevation of K, 8°
Angle of depression of C, 7°
Angle of depression of E, 3°

give the elevation in feet of the three higher of these points above the lowest.

The scale of Horizontal Equivalents may be used.

7. Construct a scale of Horizontal Equivalents for 60 feet vertical at the scale of 3·5 inches to a mile, according to the data in the preceding chapter, and figure the distances corresponding.

8. Lay down the following triangulation, scale 8 inches to a mile.

Base A B 790 yards long.

At A, bearing of B, 358°	At D, bearing of E, 346° 30′
,, ,, C, 304°	At C, bearing of G, 345°
,, ,, D, 59°	,, ,, F, 215°
,, ,, F, 261°	,, ,,

At B, bearing of C, 239°		Interpolated at X
"	" G, 287° 30′	G, 28°
"	" E, 64° 45′	C, 103°
"	" D, 126° 30′	

The points G, X, F, A, D, are on the coast line.

C, B, E, are the summits of hills respectively 115, 135, and 154 feet above the sea.

D is a point on a cliff 40 feet high.

The lowest part of the ground on the line C B is 45 feet, here a stream commences, which flows into the sea at A.

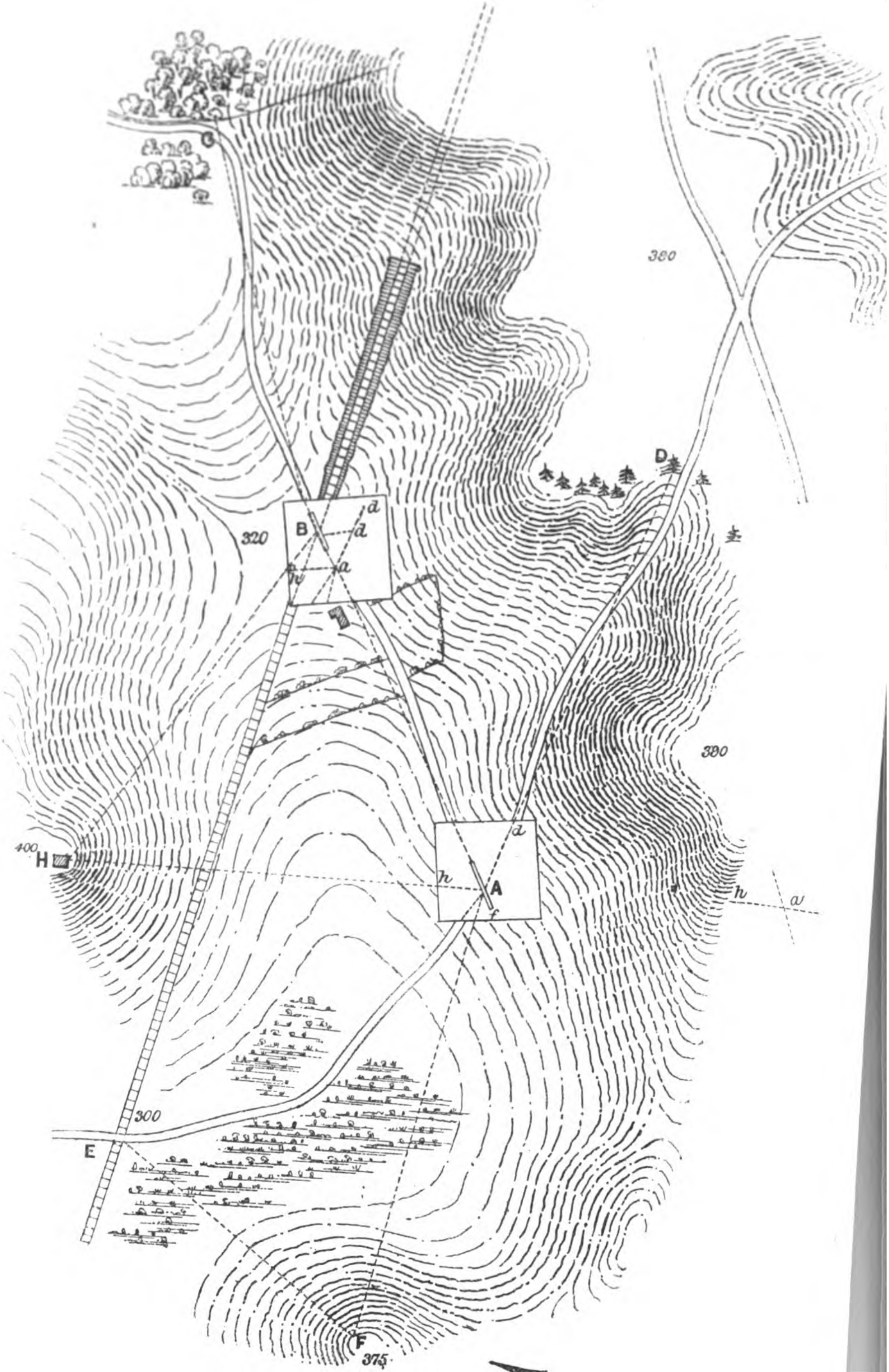
The lowest part of the ground on the line B E is 108 feet.

Give a contour sketch of the ground.

PLATE X

To face p

SKETCH WITHOUT INSTRUMENTS.



Scale 6 Inches to 1 Mile.

The figures denote altitudes in feet (by estimation), the lowest point being assumed as 300 above Sea Level.

To face p. 73.

SECTION IX.

SKETCHING WITHOUT INSTRUMENTS.

The ability to sketch well without instruments can hardly be overrated as a military accomplishment, as under the exigencies of service such conditions may often be imposed.

Military sketching may be performed without the assistance of instruments, with sufficient accuracy for tactical purposes, if the work be undertaken with judgment. In "eye sketching" (as it is sometimes termed), it is particularly necessary to bear in mind the principle of working from the whole to a part.

The kind of surveying about to be described is so simple that it would seem to be that which a beginner should first learn, but in order to ensure success an officer must first practice the more regular processes of surveying.

All that is required is a straight edged piece of wood, a scale of yards, and the back of a book or a sheet of paper fastened on a board, to draw upon.

To traverse a road. Draw a line on the paper in any convenient direction to represent the middle of the road. Lay the sketch on the ground A, Plate X., with the ruler along this line, and shift the whole sketch until the ruler is directed up the road towards B, this can be best done by retiring a few paces so as to get the whole length of the ruler in focus.

When the sketch is thus arranged with this line agreeing with the corresponding imaginary line on the ground, remove the ruler and direct it in turn on the tree at D and on any remarkable points that may be required, and draw lines towards them, being careful not to disturb the position of the sketch whilst doing so.*

Pace forwards towards B as far as the forward angle follows the road, sketching in all objects such as houses, fences, hills, &c., on each side when they are perpendicular to the forward angle. If there is time enough these offsets are paced, otherwise their length is judged; one should be able thus to sketch the ground for 200 or 300 yards on each side with sufficient accuracy.

When it becomes necessary to observe a fresh forward angle at B, lay the sketch on the ground again with the ruler coinciding with the line just traversed and directed on the starting point A. This line is thereby again adjusted to correspond with the same imaginary line on the ground, and the position of the sketch is now similar to that it occupied at A. Remove the ruler and direct it on the next forward angle C, on H (to fix its position by intersection), also down the railway. Having traversed up to C, the next forward angle is obtained by adjusting the sketch on the back station B, and so on.

This is in fact back angle traversing,† and the first forward angle becomes the "zero line" of the sketch to which all the others are related.

* A plane table may be used in practising this method of sketching. It consists of a drawing board fixed on a tripod stand, forming a convenient drawing-table in the field. The top can be turned round, so that the sketch is easily made to correspond with the ground as described above, but being cumbrous and conspicuous, it is not recommended for military sketching, where rapidity and secrecy are essential.

† This term expresses the system of obtaining the direction of the required forward angle with reference to the previous one, instead of to the meridian as is the case when the compass is used. It is the method usually employed when the Theodolite is used.

A few general rules must be observed in order to obtain good results.

I.—The forward angles to be as long as possible, never observe from a short back angle, consider well what line will carry you farthest in the required direction, and if a road winds slightly take the line on some point far along it (as from A to D and from B to C), and put in the curves by eye. These curves will appear greater than they really are, as we see them foreshortened.

Or if the nature of the ground admits, pace along the forward angle and judge the length of offsets to the road.

II.—The sketch must be laid exactly *on* the forward line when a fresh direction is to be observed; always, therefore, observe the line on an object as distant as possible, and by taking up an intermediate point of alignment (Note Page 43), you will know when you have returned to the line, after following a winding road.

III.—Commence the sketch near the middle of the ground and start in a fresh direction from this point occasionally. Thus, errors will not be carried on or accumulate. This precaution is all the more necessary as it is not easy to check the accuracy of the work in this system.

A triangulation may be constructed if required with as great accuracy as with the Prismatic Compass, by intersections from both ends of a measured base, or Stations may be fixed by intersecting them from different points during the progress of the work, whenever the sketch is adjusted on the ground.

A process somewhat resembling interpolation may also be carried out. Having at the commencement of the sketch drawn a line of direction from A towards F, we may, if subsequently working near this point, find its position on the line in the following manner: adjust the sketch to the ground as already described by means of the line AF, lay the ruler with its edge touching some point E on the paper already determined, and turn it towards the corresponding point E in the field, the intersection of the line thus obtained with the line from A will fix the position of the point F.*

In sketching hills, attention is to be paid to the position and direction of the watersheds and watercourses; these alone, if shown on the sketch, will give a fair idea of the configuration of the ground. The form and slope of the features may be rapidly represented by contours.

The true North may be shown *approximately* by adjusting the sketch on the ground and drawing a line coinciding with the shadow of a plumb line at noon, the accuracy of this depends, of course, on the time of the year, the sun being many degrees distant from true South at noon generally.

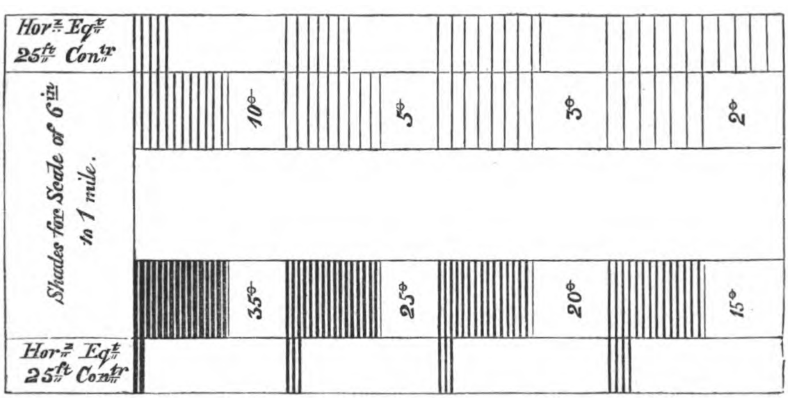
* Or one may find his place by aligning himself on two visible objects H, A, which have been fixed on the sketch, he now knows his position to be somewhere on the line a, h, and can determine the spot by an intersection from some third point D or F as described.

SECTION X.

SHADING AND DRAWING FROM MODELS, ETC.

With a view to produce uniformity of style in military drawing, a "Scale of Shade,"* Fig. 34, has been adopted, defining the strength and number of the hâchures by which certain slopes are to be represented at all scales.

Fig. 34.



To shade a contoured plan, first ascertain the slope which most nearly corresponds by applying the scale of horizontal equivalents on the outer edge, to the space between any two contours, perpendicular to them. Apply the edge of the scale

* The scale of shade is derived from analysis of the work of the most experienced military draughtsmen. It will not be found suitable for the representation of ground at scales smaller than 4 inches to a mile, unless the features are very large. Even at 6 inches to a mile it is impossible to represent small features without employing a more minute hâchure.

of shade given for that slope, and draw a few short touches as if in continuation of the lines given, of exactly the same thickness, as shown a a, Plate XI, III.

Mark off a few hâchures here and there in this manner, wherever the distance between the contours varies; so as to obtain a key to the tone of shade of the whole. Hills should be shaded from the top downwards, and the different degrees of shade expressing the varying steepness blended in a natural manner.

The axis of each row of hâchures must be at right angles t the contours, as *a a*, never as *b b*, Plate XI., III.

Each touch is to partake of the same amount of curv the contours between which it lies.

The shading must not be carried round a hill in b between two contours at a time, this would prevent the effect of roundness of forms produced by blending the shades.

In drawing the darker shades the pen must be held rather flat, and with both nibs bearing equally on the paper.

The position of the sketch is to be shifted as required, so that the hâchures may be drawn towards the draughtsman.

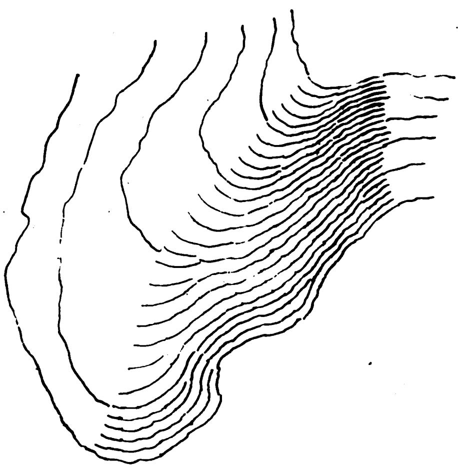
Each touch is to be of the same thickness throughout and to be drawn quite firmly. In the darker shades the touch is to be shorter than in the lighter, which may be drawn slightly broken, so as to avoid the disagreeable effect of continuous lines; for the same reason, the hâchures should not be joined to each other as in the figure I.

Neither should they be always commenced opposite the intervals between the adjoining hâchures, which produces an equally disagreeable effect, II.

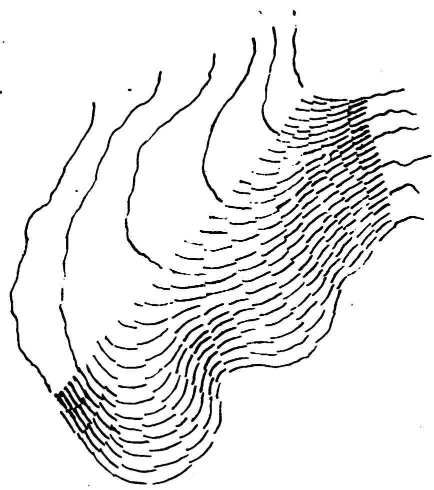
A middle course between the two produces the best effect, III.

The length of the touches should be varied a little so as to break up the rows and prevent the eye from being attracted to the spaces between.

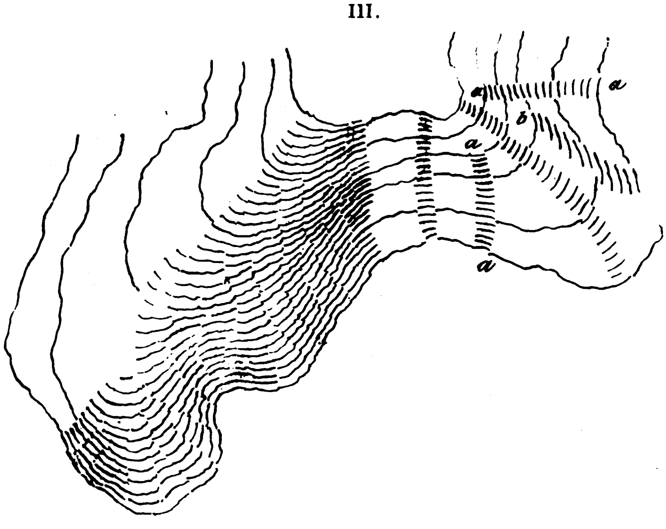
I.



II.



III.



The manipulation in shading by rule is of necessity somewhat cramped, and a beginner should draw very slowly, each touch being executed with care and deliberation; freedom of execution will follow with practice.

The pen or pencil is to be held firmly and near the point. If a pencil be used, it should be turned round in the fingers between every few touches so as to bring an angle of the lead to work which will produce a bright clear line; if a pen, it should be fine enough to produce the touches expressing 2°, but it should not be stiff, one that has been used a little will work more pleasantly than a new one.

The hâchures to be drawn from left to right (as in writing) so that the point of the pen may not hide the adjacent hâchure and that the next may be placed at the desired distance from it.

In order to distinguish the contours through the shading, they are to be chain dotted or drawn in colour, but in such a manner as not to impair the effect of the shading by being too prominent.

The maximum shade given in the scale is for 35°, natural slopes steeper than this are rarely met with except in rocky ground. If they exist in the drawing, the draughtsman may express them by increasing the strength of the touch.

Beyond 45° ground is nearly impracticable, and may be represented manner by vertical or broken touches.

When the beginner has copied the series of examples and obtained the proper touch, he should practice drawing from models, commencing with those on which the contours are marked, and continuing with smooth models; these latter are the very best preparation he can have for hill sketching.

A knowledge of the general formation of hills and the manner in which they are joined to each other is necessary, that the draughtsman may direct his attention to the proper points.

ranges of hills branching from the main ridge is the water- [illegible] which will shed the rain and spring water into secondary watercourses in opposite directions.

In sketching from the smooth model the draughtsman must view it from a [illegible] faintly the position of [illegible] hills by mea[illegible] river[illegible] wards. They will take the extreme of their inward or re-entering bends on crossing the watercourse lines, and of their outward or salient curves at the secondary watersheds. If attention has been paid to the position of contours on the models on which they are marked, no difficulty should now be experienced in placing the contours at such distances as to express fairly the relative steepness of the various features.

The drawing lastly to be shaded by scale of shade. The feature that all beginners find most difficulty in shading correctly, is the neck or col. "n," Fig. 36, joining adjacent eminences.

Fig. 36.

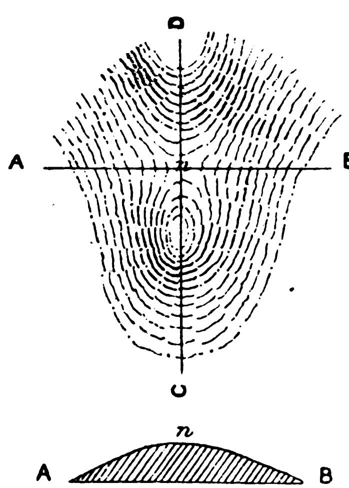
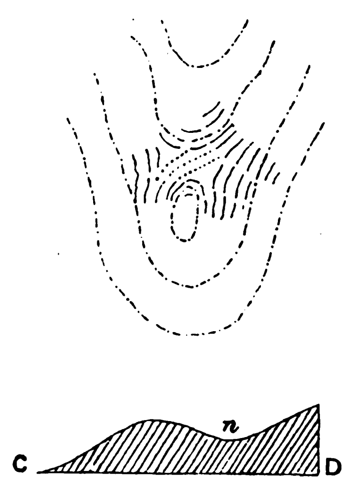


Fig. 37.



The ground at this spot being nearly level, the hâchures must be very light and wide apart. Fig. 36 is correctly expressed, the mistake is often made of carrying the hâchures across the col as in Fig. 37, (incorrect touches dotted).

As regards the conventional signs used to express detail Plate I., (given at the beginning) it will be remarked that signs expressing perpendicular objects, hedge-rows, trees, &c.,

are drawn perpendicularly (or parallel to the sides of the drawing), with their shadows falling to the right. Those expressing marshy ground, water, &c., are drawn horizontally. A few pencil lines should be drawn parallel to the top or to the sides of the paper to guide the hand.

Colour is of great use to express detail. Roads, if metalled, should be coloured Burnt Sienna. Buildings of stone or brick Crimson Lake or Venetian Red. Water, Prussian or Cobalt blue. Cultivated ground, pale yellow. Wood green, if fir wood of a neutral and sombre tint, if oak or beech, of a warm green. Sand, of a suitable yellow. Heath may be distinguished from cultivated land by a flat shade of pale purple.

Troops, by the national colour of their uniform.

When colour is used to denote wood, cultivation, &c., it should be laid on before the hill shading or any drawing, as Indian ink is apt to wash up. The drawing should be held in a sloping position, and the wash of colour laid on with a full brush.

All printing to be horizontal, with the exception of the names or directions of railways, rivers, canals, or roads.

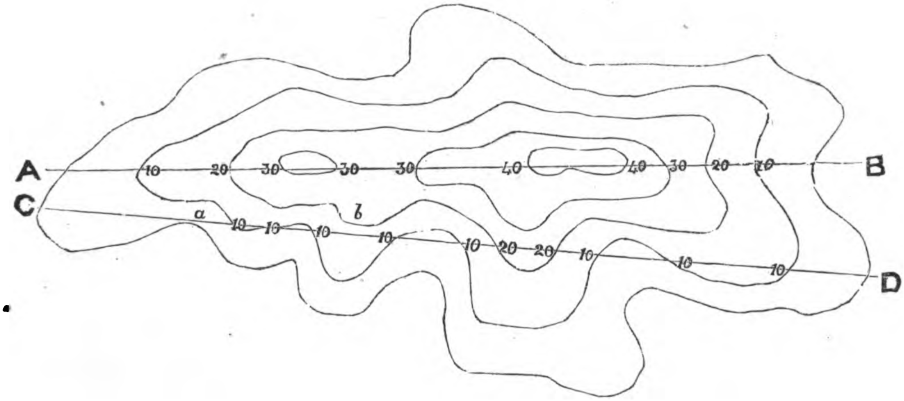
SECTION XI.

SECTIONS.

A section is the representation of the intersection of a hill by a vertical plane.

A true section of a hill will not convey an adequate impression of its steepness. A slope of 15°, for instance, which is a fatiguing ascent, appears very trifling on paper. In order to convey a more striking idea, two different scales are generally used in drawing sections, the vertical scale being 3 or 4 times greater than the horizontal, this exaggeration is usually expressed as "heights to distances 4 to 1."

Fig. 38.

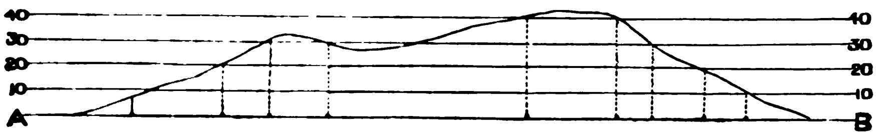


Scale 15 inches to a Mile, contours 10 feet. Heights to distances 5 to 1.

To draw a section on A B, Fig. 38. The contours being at a vertical interval of 10 feet, number the heights at the intersections of the contours by the section line as shown.

Draw a horizontal line A B, Fig. 39, called the datum line.

Fig. 39.



Heights to distances 5 to 1.

Parallel to this draw as many lines as are required, representing the planes of the contours at the equidistance required by the conditions.

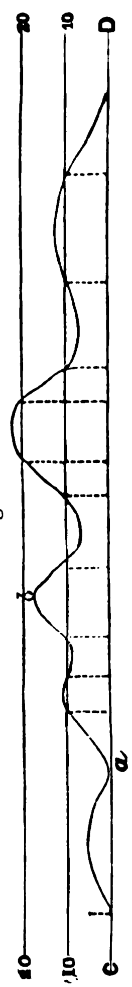


Fig. 40.

Heights to distances 8 to 1.

Here 40 feet being the highest contour, draw the upper line at that distance from A B, multiplied by 5 (the vertical exaggeration) = 200 feet.

The scale being 15 inches to a mile (or 5280 feet) $\frac{200 \times 15}{5280} = \cdot 57$ inch, distance between A B and the highest contour.

Place between these the lines for the intermediate contours.*

Lay a straight edged slip of paper along the section line A B, Fig. 38, and mark on it the points of intersection and the figured heights. Transfer these to the datum line, Fig. 39, and raise perpendiculars to intersect the corresponding heights. Join these points.

Again, in Fig. 40, the vertical exaggeration being 8, the distance of the 20 feet contour from C D is

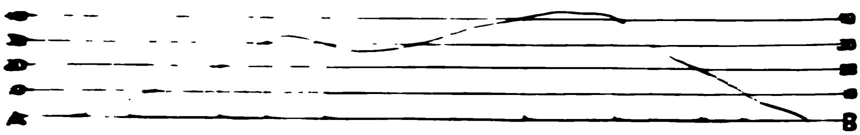
* If the scale of the plan happens to suit those given on the ivory protractor, the distance between the parallel lines may be taken off it instead of from a scale of inches, taking care to reduce the feet to yards before doing so.

$$\frac{20 \times 8 \times 15}{5280} = \cdot 47 \text{ inch.}$$

In drawing the section, attention should be paid not only to the representation of the correct heights at the points of intersection, but also at every part of the section line. This can be seen by noticing its proximity to the adjacent contours on the plan. Thus at a, Fig 38, the section line nearly touches the datum line, and at b, reaches within about a quarter of a contour of the 20′ level. The section is drawn similarly at a and b, Fig. 40.

Draw a horizontal line A B, Fig. 39, called the datum line.

Fig. 39.



Heights to distances 8 to 1.

Parallel to this draw as many lines as are required, representing the planes of the contours at the equidistance required by the conditions.

Here 40 feet being the highest contour, draw the upper line at that distance from A B multiplied by 8 (the vertical exaggeration) = 320 feet.

The scale being 16 inches to a mile or 5280 feet, $\frac{320 \times 16}{5280} = .97$ inch, distance between A B and the highest contour.

Place between these the lines for the intermediate contours.*

Lay a straight-edged slip of paper along the section line A B, Fig. 38, and mark on it the points of intersection and the figured heights. Transfer these to the datum line, Fig. 39, and raise perpendiculars to intersect the corresponding heights. Join these points.

Again, in Fig. 40, the vertical exaggeration being 8, the distance of the 20 feet contour from C D is

* If the scale of the plan happens to suit those given on the ivory protractor, the distances between the parallel lines may be taken off it instead of from a scale of inches, taking care to reduce the feet to yards before doing so.

$$\frac{20 \times 5 \times 15}{3200} = \cdot 47 \text{ inch.}$$

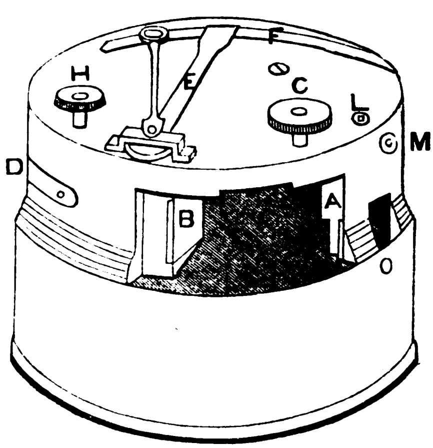
In drawing the section attention should be paid not only to the representation of the correct heights at the points of intersection, but also to every part of the section line. This can be seen by noticing its proximity to the adjacent contours on the plan. Thus at a, Fig. 38, the section line nearly touches the contour line, and at b reaches within about a quarter of a contour of the 20' level. The section is drawn similarly at a and b, Fig. 4[illegible].

SECTION XII.

THE POCKET SEXTANT.

This instrument combines many valuable qualities. It approaches the Theodolite in accuracy, measuring angles to a minute, and is only about 3 inches in diameter and 1½ inches deep. Observations may be taken with it with rapidity and certainty even on horseback, or in high wind; it is not liable to injury and is easily adjusted.

Fig. 41.



The Sextant is represented with its cover screwed on underneath it, as it should be when in use. At other times, the cover being screwed down over the face excludes dirt and dust, and protects it.

The chief use of the pocket sextant is for the observation of the triangulation. It is also convenient for laying out field works, the measurement of heights, distances, &c.

* Its advantages, in comparison with the compass are its non-liability to local attraction and its greater accuracy, but it is not so generally useful, being inconvenient for filling in details and inapplicable to traversing.

The Sextant is one of the class called reflecting instruments, wherein mirrors are used. It contains two, A and B. The mirror A, called the horizon glass, is fixed perpendicular to the plane of the instrument, the upper half only of this glass is silvered, the lower and transparent half is opposite the opening O. The mirror B, called the index mirror, is moved by the milled-headed screw C, which communicates with it by a rack and pinion movement; it carries with it the index arm E, which is provided with a vernier scale reading minutes on a graduated arc F, on the face of the instrument (Page 8).

At D there is a slide in some instruments, with coloured glasses, which may be interposed when a solar observation is taken; and at the far side of the instrument, which cannot be shown in the figure, is an opening in the box, at which are two levers, by means of which other coloured glasses may be interposed in the interior for the same purpose.

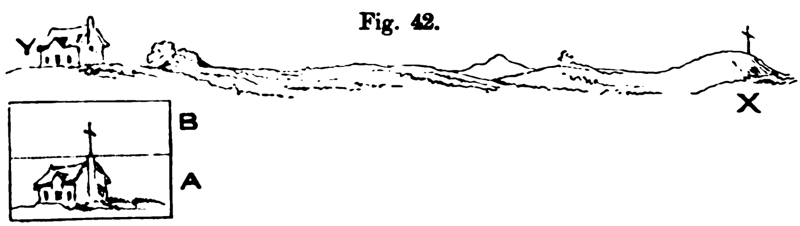
To observe an angle with the Pocket Sextant. Screw in the telescope with which most are provided at D, or, if unprovided with a telescope, draw aside the coloured glasses in the slide and look through a small hole there at the *left hand* object Y through the opening O.

Hold the lower part of the Sextant with the left hand, and with the right turn the screw C (raising the right elbow high

* The Pocket Sextant may be used to find the latitude by the meridian altitude of the sun, but as these pages treat merely of subjects connected with sketches of small portions of country, it would be out of place to introduce the subject.

so that it may not interpose between the instrument and the right hand object) until the right hand object X is reflected by the index mirror B to the upper or silvered half of the horizon glass A, and appears in coincidence with the left hand object Y (seen by direct vision through the lower or transpa-

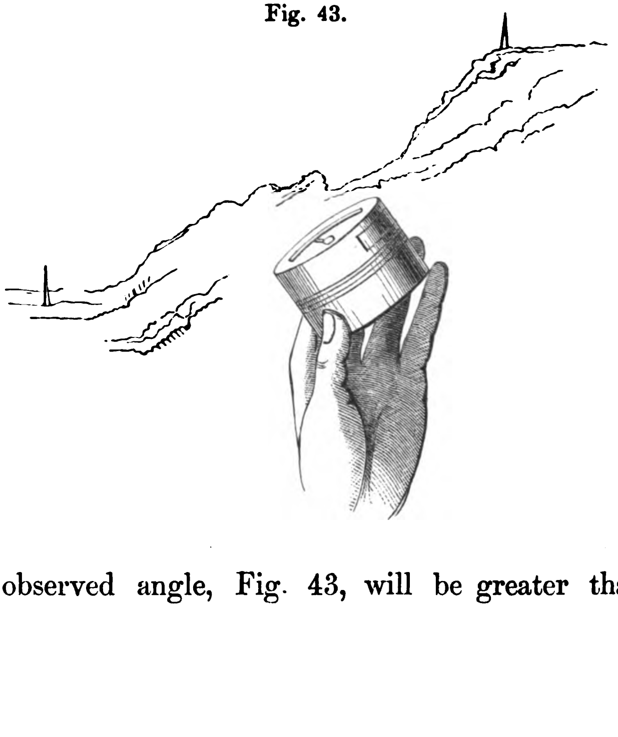
Fig. 42.



rent half of that glass). The angle may then be read off the vernier by the magnifying glass.

In the Sextant, in order to bring the reflected image into coincidence with that seen by direct vision, it is necessary to hold the instrument so that its plane is parallel to that of the two objects.

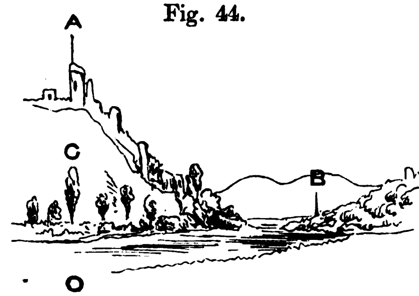
Fig. 43.



The observed angle, Fig. 43, will be greater than the horizontal angle, the observation being made in an oblique plane.

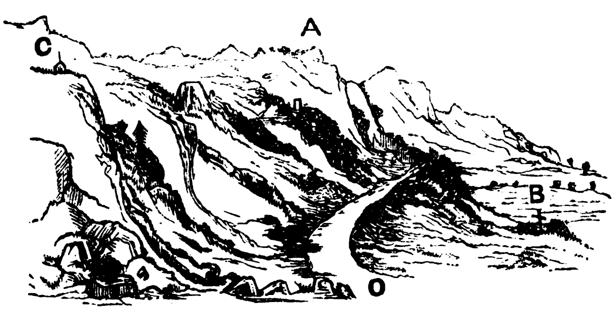
In order to overcome this defect, O being the point of observation, select some point C, either vertically over or under one of the objects, and nearly in the same horizontal plane as the other, and observe the angle C O B between these, instead of A O B.

Fig. 44.



Another method of diminishing this error is (supposing it were desired to measure the angle A O B), to select a point

Fig. 45



C 90° or 100° distant, and observe the angles between each of the objects and that point (C O A, C O B). The difference between these will be more nearly the true horizontal angle.

The Pocket Sextant will not measure an angle greater than about 120°. When the angular distance is larger than this, we should select a point lying between the objects, and observe the angle between it and each of them. The sum of these will be the required angle.

We frequently find that objects distinct enough when viewed with the naked eye, become invisible when the Sextant is used, and that those which have a background of sky are most distinct. We should, in this case, when the clearest object is on the left make it that which is reflected by the index glass, by holding the Sextant upside down and bringing the left hand object to the right.

To observe a vertical angle. Hold the Sextant in the right hand with its face to the left, and, looking at the lower object by direct vision, bring the upper down into coincidence with it, using the left hand to turn the screw C.

Before proceeding to take angles with the Pocket Sextant, we should ascertain whether it is in perfect adjustment. The points to be observed are two.

1st. That the two mirrors are parallel to each other when the zero of the vernier coincides with that of the graduated arc.

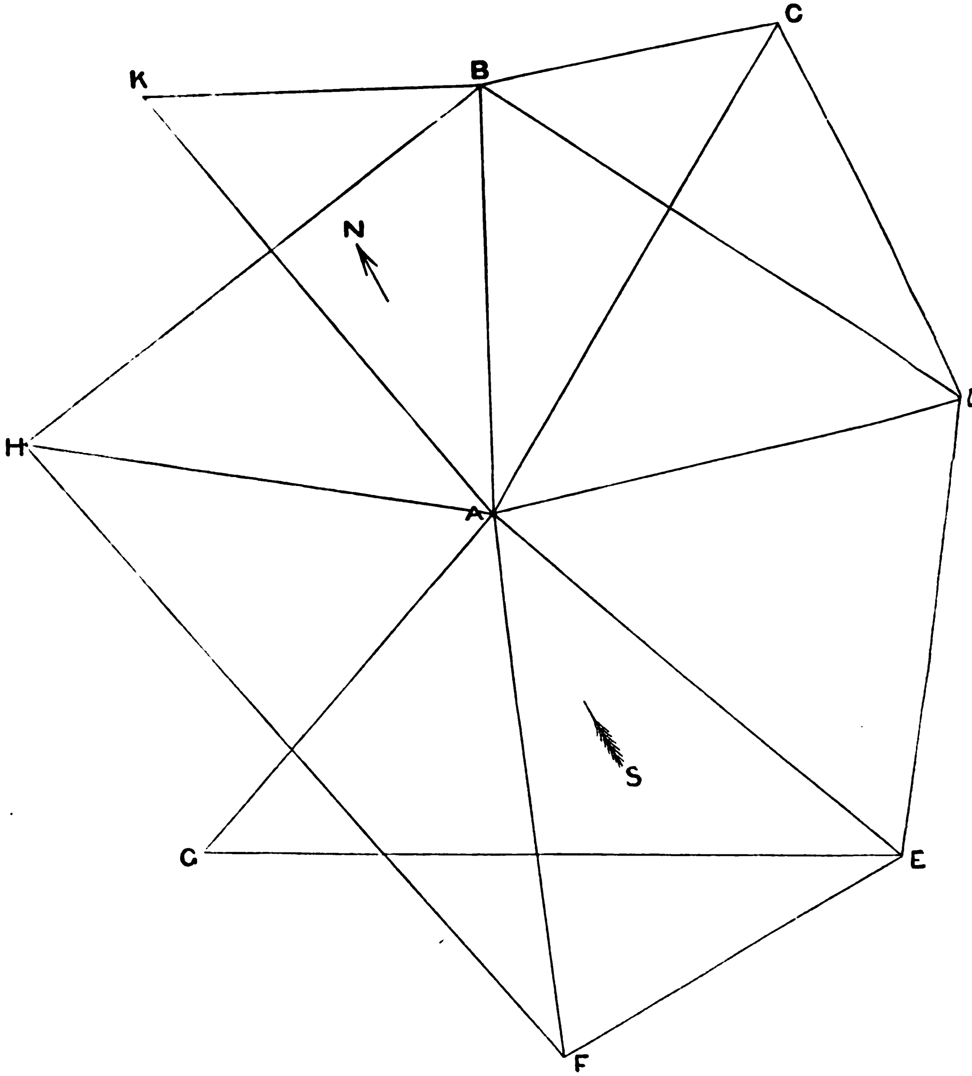
2nd. That the horizon glass is perpendicular to the plane of the instrument.

For the first of these, select a well-defined object, such as the angle of a house, or a pole, about ½ a mile distant, and bring the reflected and the direct image of this into coincidence; then examine the vernier, and if it is at zero the instrument requires no alteration; if it does not coincide with zero by a few minutes, note down the angle recorded as the "index error," to be added to or subtracted from all observed angles. If the zero of the vernier rests at, say, 5′ to the right of the zero of the arc, we note it as "index error + 5," and subtract that quantity from all observed angles. If it rests at the left of the zero (called the arc of excess), we ascertain the angle so recorded by counting for minutes on the vernier as if it were numbered the reverse way, from right to left. This quantity is noted as "index error minus –" and is to be *added* to all observed angles.

If the index error be very great, we may adjust the instrument so as to correct it. Place the two zeros in coincidence, remove the key H, apply it to the square at M, and turn it until the direct and reflected images coincide exactly. This

PLATE XII.

To face p. 93.



adjustment need not be frequently effected; if the index error is small, it is simpler to take note of it as a constant error, as described.

The other adjustment (to correct the perpendicularity of the horizon glass to the plane of the instrument) is effected by observing whether the reflected and the direct images of the distant horizon appear as *one*. If two horizons appear, we apply the key at L, and turn it till they agree.

By turning down the coloured glasses, and bringing the reflected and the direct images of the sun together, we may satisfy ourselves of the correctness of both adjustments of the Sextant at once, if the vernier reads O on the graduated arc.

The adjustments of the Sextant are tested by observing a distant object; because at short distances, under 100 yards or so, the parallax of the instrument becomes apparent. Instrumental parallax expresses the error caused in observations of near objects by the necessity of placing the eye *at one side* of the index mirror. Were it possible to observe the angle from the centre there would be no such error. As it is, it is very small, and at 150 or 200 yards is inappreciable.

OBSERVATION OF THE TRIANGULATION.

The angles observed with the Sextant are the angular distances between *visible* objects, differing from the Prismatic Compass which gives the angular distances from an *imaginary line*, the magnetic meridian.

In observing the triangulation (Plate XII.) with the Pocket Sextant, firstly observe the round of angles at A. Bring the Station C to coincide with B, and read the angle B A C 30° 4′. Next bring D to B, the angle B A D = 76° 14′. We find that the next angle B A E is greater than can be measured by the Sextant, observe instead D A E 55° 28′ (the angular distance of D from B being known), also D A F = 97° 48′.

Complete the observations by the angles K A B, H A B, G A H, F A H, taking care in every case to measure either from or to a Station, the angular distance of which from the other end of the base B has been already measured.

The angles would be entered in the Field Book, thus:—

At A	from B to C . . .	30° 4′
	„ to D . . .	76° 14′
	D to E . . .	55° 28′
	„ to F . . .	97° 48′
	K to B . . .	37° 13′
	H to B . . .	79° 2′
	G to H . . .	58° 27′
	F to H . . .	106° 56′

If the Stations are situated nearly in the same horizontal plane, or if proper care has been taken to avoid oblique observations as described, the sum of the whole round of angles should be 360° within a few minutes.

A diagram of the figure of the triangulation should be made in the field, in order to guard against the omission of any necessary observation.

The bearing of the base A B should be taken at the same time, with the prismatic compass, 24° 15′.

The next series of angles would be observed at B, and measured either to or from the known point A.

At B	from A to H . .	52° 32′
	„ to K . . .	89° 1′
	D to A . . .	54° 53′
	C to A . . .	100° 4′

Next, At D	from A to C . . .	80° 4′
	E to A . . .	69° 55′

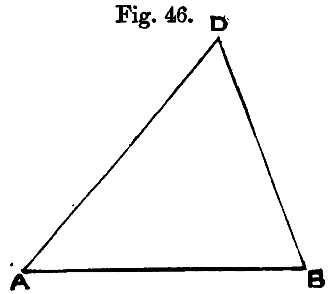
At E	from F to A	. . .	71° 30′
	G to A	. . .	39° 16′
At F	from H to A	. . .	33° 40′

This last observation is taken in order to apply the angular test, if the line F H, when laid down on the plan, be found to pass through H, already fixed, we may conclude that no great error has taken place in observation or construction.

When a Station is fixed by an acute intersection, its position should be verified by several observations in this way.

As the third angle of any triangle is the supplement of the others, it is immaterial which two angles we observe, and it occasionally may save time to observe the second angle at the vertex in preference to the other end of the base. For instance, in the triangle A B D, having observed at one end of the base the angle D A B = 49° 6′, we might find it convenient to observe the second angle at D 50° 20′ instead of at the other end of the base B.

Fig. 46.



Then A B D is known $180° - (50° 20' + 49° 6') = 80° 34'$.

When it is intended not to calculate the length of the sides of the triangles, it may sometimes be convenient to measure the angular distance from some Station already fixed, although belonging to a different triangle, and although the resulting figure may not be a triangle.

For instance, when at E, (Plate XII.) wishing to observe the direction of F and G, we might find it easier to observe the angles between these points and H, instead of A, if the latter be obscure, or not in the same horizontal plane.

N.B.—The subject of this Section does not form part of the course of instruction.

SECTION XIII.

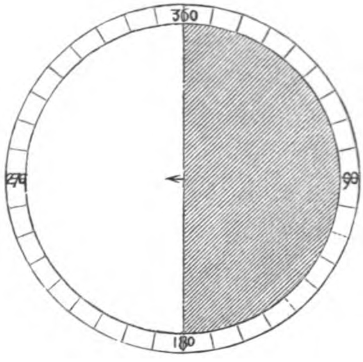
CONSTRUCTION OF THE TRIANGULATION OBSERVED WITH THE POCKET SEXTANT.—SCALE OF CHORDS BY CALCULATION.

When the triangulation observed with the Pocket Sextant is to be laid down by construction, a larger protractor than the common ivory sketching protractor must be used, if the accuracy of the construction is to be to some extent proportionate to the nicety of the observations.

Of the many forms in which they are manufactured, it will be sufficient to describe the printed cardboard protractor, which will probably be that used by the beginner.

These are made in sizes varying from about 12 to 18 inches diameter, and are graduated to as small as 15′, so that angles

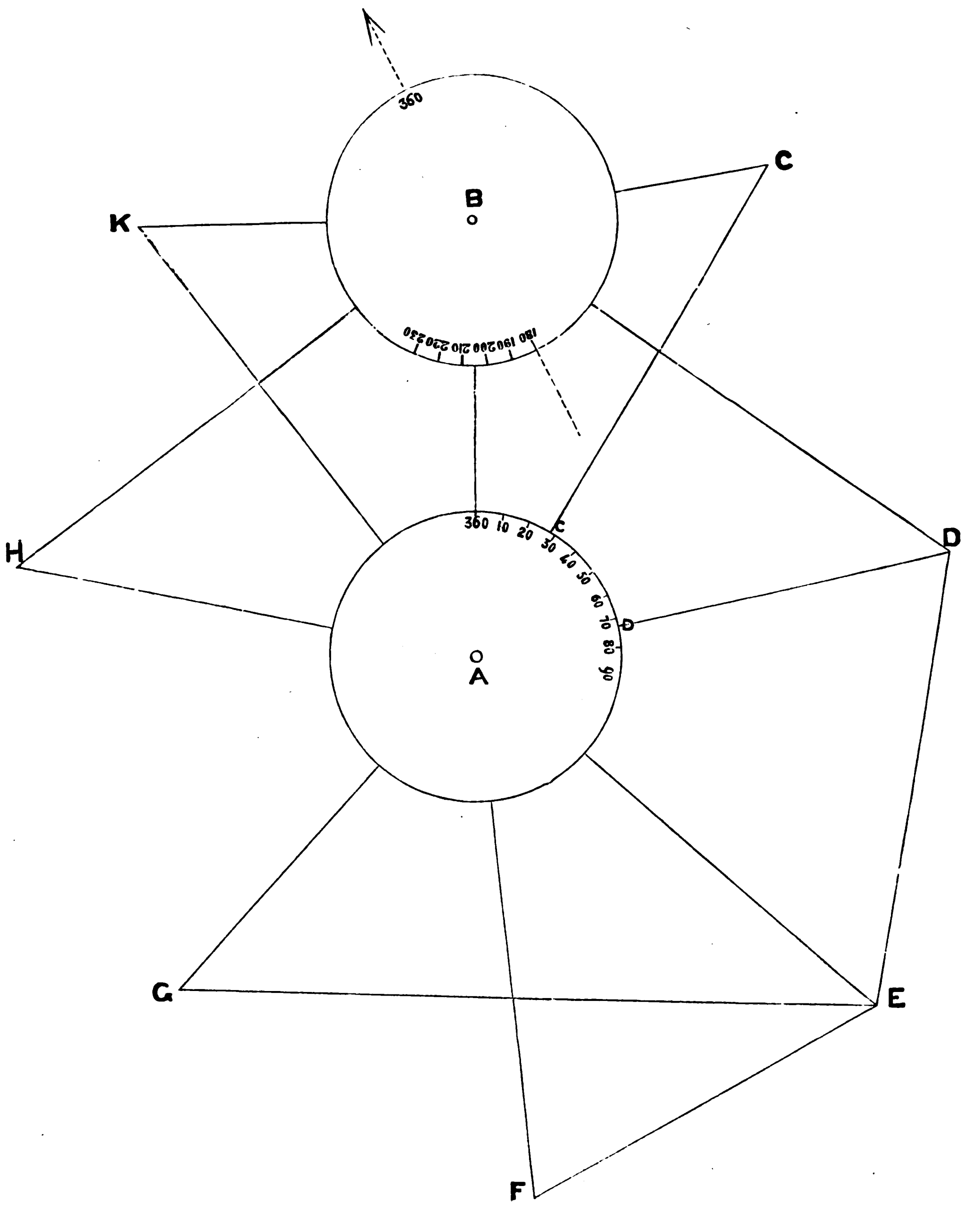
Fig. 47.



may be laid down by estimation within 5′. A small hole should be cut out at the centre for the convenience of adjust-

PLATE XIII.

To face p. 96.



ing them to any point on the plan: these protractors are very useful, both for constructing the triangulation and for plotting the details.*

In laying down the triangulation we merely repeat with the protractor the observations taken, by adjusting the centre to the point *at* which, and the zero towards the point *from* which, the measurements were taken: mark off the position of the angles, and produce them to intersection as previously described.

A point A having been assumed on the plan, A B is drawn in any convenient direction, 679 yards long, scale 6 inches to a mile.

The first observations in the Field Book (Page 81) being

At A	from B to C	. . .	30° 4′
	„ to D	. . .	76° 14′

The protractor is shown adjusted with its centre at the point A, and the zero coinciding with A B, the direction of C and D is marked off with a fine pointed pencil.

The next observations being,

At A	from D to E	. . .	55° 28′
	„ to F	. . .	97° 48′

the zero must now be adjusted to the line A D, and the directions of E and F marked, &c.

If the triangulation is to be constructed on paper already prepared with meridians, the base must *first* be laid down in its proper relation to them, and the construction of the figure then proceeded with.

* The circular cardboard protractors sometimes have a piece of the shape shown by the shaded portion cut out and the centre marked. They are also made in the form of a ring, when the centre has to be found by laying a straight edge across the diameter from 90° to 270°.

If on plain paper, the direction of the meridian may be laid down after the figure has been constructed. The protractor is adjusted for this purpose with its centre at the point of observation, and the observed bearing in coincidence with the base or other observed side: the zero then indicates the North, and 180 South. These points should be permanently marked, and all meridians required in the course of the work are referred to them.*

The protractor B is shown in Plate II. adjusted at B, to lay down the meridian, the observed bearing of A from B being 204° 15′.

SCALE OF CHORDS.

If large protractors are not procurable, the triangulation may be constructed by the scale of chords which is engraved on most protractors.

* There are many varieties of protractors furnished with verniers, with which a higher degree of accuracy is supposed to be obtained. These are of metal, either circular or semi-circular in form, the centre usually marked by a fine cross on glass. They are provided with a radial arm carrying a vernier scale, capable of being adjusted to a minute on the graduated circumference; this arm generally extends to some inches beyond the circle, its edge being the prolongation of the radius. The vernier is set at the required angle and clamped before the protractor is adjusted on the plan.

Circular protractors are also made with points on the reverse side to fix them on the paper; they have two radial bars, at the extremity of one of which is a vernier scale for adjustment on the graduated circumference, and, of the other, a pinion working in a toothed rack round the instrument; both arms are provided with a pricker, by which the position of the required angle is marked on the paper. This instrument, however, does not find much favour among surveyors, on account of the manner in which it defaces the paper, and because it is delicate and easily put out of order.

Circular and semi-circular protractors of different sizes, with less pretension to accuracy, are made of metal, graduated to as small as 20 minutes, without vernier. I prefer the cardboard to most of these, being less tiresome to the eye-sight; whilst sufficiently accurate.

To set off an angle. With the point of observation as a centre, describe an arc with a radius of 60 degrees taken from the scale of chords.

On this arc set off the angular distance (taken on the scale of chords), from its point of intersection with the base; a right line produced through this point from the point of observation, is in the required direction.

BY CALCULATION.

When the survey is of any great extent the triangles should be laid down by the length of their side found by calculation, instead of by their angles; by this method a much higher degree of accuracy may be obtained. In a survey of from 10 square miles upwards, at any rate, some of the principal Stations should be so determined.

For the solution of triangles in surveying, we require to know the length of one of the sides, and two of the angles, or two sides and the angle contained between them; and as the former is more simple in calculation and in observation, it will be that which will be almost invariably given.

For this the rule is, that, *the sides are proportional to the sines of the opposite angles.*

In the triangulation, Plate XII., we know in the triangle A B D the length of A B = 3086 links, the angles B A D 76° 14′, A B D 54° 53′, and A D B 48° 53′.* To find the length of A D (or b).

$$\sin. D : \sin. B : : d : b$$

$$\text{by natural sines } b = \frac{d \sin. B}{\sin. D}$$

$$\text{by logarithms } L\,b = L\,d + L \sin. B - L \sin. D$$

$$= 3{\cdot}489396 + 9{\cdot}912744 - 9{\cdot}877010 = L\,b.$$

* If two angles A and B only had been observed, the third D would be their supplement,

$$D = 180° - (A + B).$$

If a large number of triangles are to be calculated, they may be arranged in a convenient tabular form, using the cosecant of the angle opposite the known side instead of the log sine; then all the calculations are additive.

A	Angles.	Angles.	Logarithmic Computation.	Distance.	Side.	Remarks.
ABD			3·489396	3086	A B	Base.
	A D B	48° 53′	0·122990	"	"	cosecant.
	A B D	54° 53′	9·912744	"	"	sine.
	B A D	76° 14′	9·987341	"	"	sine.
			3·525130	3351	A D	
			3·599727	3979	B D	

In this form we have the first two logs common to both sides, and if we cover the quantity not required (the third or fourth) with a slip of paper, the addition is easily made or revised.

In the other case, if we know two sides and the contained angle—

Let the known side be 1076·53, and e 2846·39, and B the contained angle 150° 7. To find the other quantities:—

The sum of the angles opposite the given sides is found by subtracting the given angle from 180°, $E + F = 180° - 150° 7' = 29° 3'$.
and $\frac{1}{2}(E + F) = 14° 31' 30''$.

The sum of the two sides is to their difference, as the tangent of half the sum of the angles at the base, to the tangent of half their difference.

$$\text{Ar. co. Log. } (e + f)\ 3922{\cdot}92 = 6{\cdot}406347$$
$$\text{Log. } (e - f)\ 1769{\cdot}86 = 3{\cdot}247939$$
$$\text{Log. tan. } \tfrac{1}{2}(E + F)\ 14° 31' 30'' = 9{\cdot}413205$$

$$\text{Log. tan. } \tfrac{1}{2}(E - F)\ 6° 39' 46'' = 9{\cdot}067491$$

Hence, $E = 21° 11' 16''$ and $F = 7° 51' 44''$.

To find the required side *b*.

$$\text{Log. cosec. E } 21^\circ\ 11'\ 16'' = 10{\cdot}441982$$
$$\text{Log. sin. B } 150^\circ\ 57' = 9{\cdot}686254$$
$$\text{Log. } e\ 2846{\cdot}39 = 3{\cdot}454296$$
$$\text{Log. } b\ 3824{\cdot}12 = 3{\cdot}582532$$

In laying down triangles by their sides we describe arcs of the required length of radius from both ends of the base, their intersection gives the required Station.

Beam compasses are employed for this purpose. This instrument is a beam of well-seasoned wood with the required scale engraved on a slip of holly or box-wood inlaid upon it. It is provided with two boxes fitting to and moveable on it, each of these has a vernier scale and a clamping screw, also needle points coincident with the zeros of the verniers.

As a substitute for this (when the required length is greater than can be taken in the opening of common compasses) we may use a slip of stout paper with two holes at the required distance, one adjusted to the centre by a needle, the other guiding a fine pointed pencil in describing the arc.

SECTION XIV.

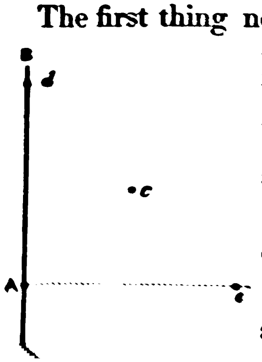
PROBLEMS IN HEIGHTS AND DISTANCES—TRACING FIGURES ON THE GROUND, &c.

In order to perform these operations readily, they should be practised on the ground as well as understood theoretically. From the fact of not having the whole figure under the eye, and of having to use a cord or tape instead of a pair of compasses, beginners generally waste much time, even in such small matters as laying down angles on the ground, and are unable to realize what appears so simple on paper.

It is better to thoroughly understand and remember one way of performing a problem than to learn several, which will probably be soon forgotten, those given are a few of the most useful and simple, requiring no tables for calculation.

The best marks are iron pins such as are used with the measuring chain, they can be stuck into any hard ground, and should have a piece of white stuff tied to them, so that they may be visible from a distance. An inelastic cord or tape is used.

The first thing necessary is to lay down a right angle or a perpendicular to a given line. This can be done in many ways, but one that can be performed *in any situation* without the assistance of a second person, is



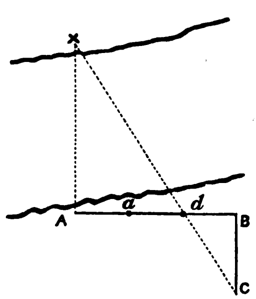
Let A be the point at which a perpendicular to the line A B is required.

Plant a peg at any convenient point *c*, about 10 or 12 feet from A. Take the length of A c and with the same length place two pegs in line with c (viz. d and e) the first on the given line.* e belongs to the perpendicular.

Problem I.

To find the breadth of a river or the distance of an inaccessible point.

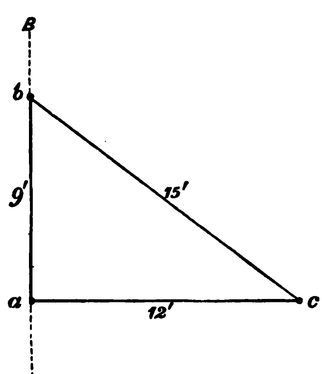
The distance of x from A being required. Place a mark at A, another at B at a distance from A proportionate to the required distance, and in the alignment of a with A (a having been in the first place marked with a picket perpendicular to A x).



Lay down B C perpendicular to A B. At a convenient point C, align a mark d with x. The triangles x A d, d B C are similar. Measure with tape C B, B d, d A.

Then d B : B C : : d A : A x.

* The simplest way of setting off angles is with the sextant. Suppose a right angle is required. Set the vernier at 90°, stand over the point where the perpendicular is required, and beckon an assistant to move right or left until the pole he carries coincides, by reflection, with that marking the other end of the given line.



Another easy way of raising a perpendicular, is by taking lengths on a cord or tape in the proportion 3, 4, 5, and applying the angle opposite the longer side to the given point.

For instance, three persons hold a tape, one at the 9th foot, the other two at the 21st and 36th.

A perpendicular being required at a to the line A B, one holds the tape at a, the other two stretch it to b and c, and a peg is stuck in the ground marking the latter.

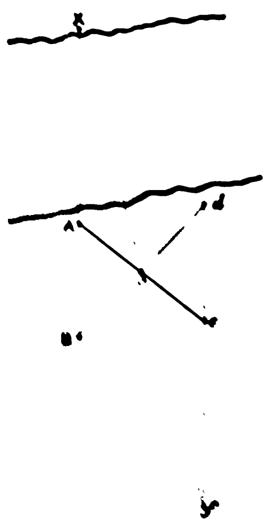
This construction is derived from Euclid I. 48.

Many other angles may be set off on the ground with a cord. 60° by making the sides of the triangle equal, 30° by halving the

If the space be cramped, it may be more convenient to make A B shorter and B C longer.

SECOND METHOD.

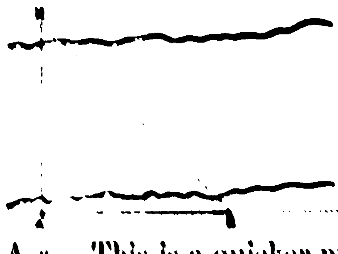
Place a mark at B in prolongation of x A, another at a convenient point c. Make $c\,d$ equal to c B and $c\,e$ equal to c A. Find f where $x\,c$ and $d\,e$ would intersect when produced. The triangles x A c, $f\,e\,c$ are similar and equal, and $e\,f$ (equal to A x) may be measured.



If provided with a prismatic compass, the distance may be found in the ordinary way by triangulation. Measure a base proportionate to the distance of the required point, from the ends observe its bearing and that of the base.

Lay down the figure to scale, (the larger the better), and measure the required line in the drawing.

WITH THE SEXTANT.



Set the vernier at 90°, and find some distant object b perpendicular to A x.

Move along this line until A and x subtend an angle of 45° at B.

Measure B a, which is equal to A x. This is a quicker method than the others.

opposite side in this triangle, 15° by again halving the opposite side, 45° by halving the opposite side to the right angle.

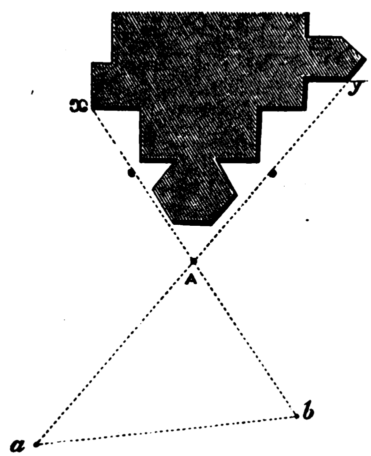
Then by adding or subtracting these to or from each other on the ground, many others may be constructed, as 75°, 105° 120° 135° 150°.

Observe that in constructing these figures on the ground, their size should be proportioned to the distance to be found.

Problem II.

To find the length of a line accessible only at the extremities, as $x y$.

Place a mark at a convenient point A ; another at a in the



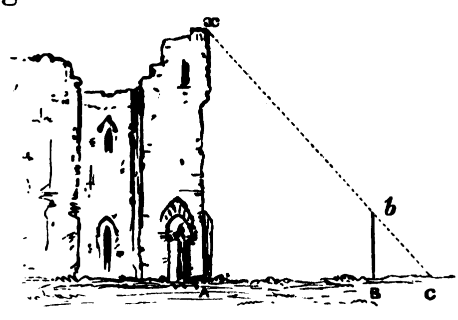
prolongation of, and equal to, Ay. And at B, making b A = A x.

The distance $a b$ is = $x y$.

Problem III.

To find without instruments the height of an object accessible at the base, on level ground.

Place a pole at any point B, and a mark at c where $x b$ produced meets the ground. Measure C B, B b and A B.



Then C B : Bb : : C A : Ax.

Or if the sun be

shining, measure the length of the shadows of the pole and of the building.

Shadow of pole : its height : : shadow of building : its height.

WITH CLINOMETER.

Advance towards or retire from the building until its top is at an angle of elevation of 45°.

The height of the building is equal to the distance from this spot to its base, plus 5 feet, or whatever may be the height of the eye from the ground.

If unprovided with a clinometer, a card may be doubled into the angle 45°, and a plumb line formed of a piece of thread and a pebble.

WITH POCKET SEXTANT.

Make a mark on the wall at the height of the eye. Set the Sextant at 45°, and retire from the building until this mark coincides with the top by reflection. Then, as before, the height is equal to this distance, plus the height of the eye.*

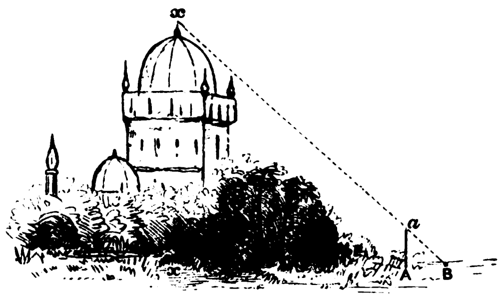
PROBLEM IV.

To find the height of an object inaccessible at the base, on level ground.

The simplest way is to combine Problems I. and III.

* Tables of tangents are prepared showing other convenient angles than 45°. Thus if we retire from the object until it subtends 26° 34′ the distance will be double its height, if 5° 43′ ten times its height, if 63° 26′ half its height, &c. However, an officer could not be expected to commit these to memory, and the table is excluded as unnecessary, since the angle 45° can in nearly every case be employed.

First find the distance of x from a convenient point B,



then erect a pole and mark on it where it is cut by the line B x. Measure A B.

Then B A : A a : : B x : x x.

Problem V.

To find the height of an object inaccessible at the base, on sloping ground.

First. Find the distance of the object by one of the methods given, Problem I. Observe the angles of elevation of the top and bottom with the clinometer. Draw the figure on paper, to a large scale; make the distance the base, from one end set off the angles of elevation which produce to intersect a perpendicular set off at the other end. Measure the height of the object by scale.

Or, to be quicker. Suppose the distance of the object to be found 67 yards, the angle of elevation at the bottom 5°, and of the top 13°. Then (as at 19·1 yards, 1° elevation gives a height of 1 foot, Page 55), the bottom of the object is approximately above the observer $\frac{67 \times 5}{19 \cdot 1} = 17 \cdot 5$ feet, and the top $\frac{67 \times 13}{19 \cdot 1} = 45 \cdot 6$ feet.

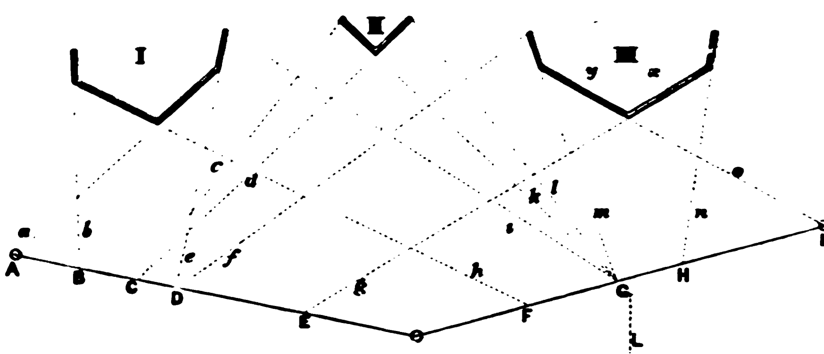
And its height is 28 feet.

These methods are only approximations sufficiently close for most purposes. The latter only suitable when the angle of elevation is small.

Problem VI.

To find the plan, size, &c., of fieldworks from a distance.

Traverse a line as A K out of observation, Halt at points



in the prolongation of the faces and observe their bearings, laying them down to scale.

Thus at A the bearing *a* gives the direction of the left face of Lunette I., when F is reached, the prolongation of the right face can be taken up; the intersection of these gives the position of the salient. The length of the faces is determined by their intersection by the bearing of the flanks *b* and *e*. The manner in which the flêche, &c., are found may be seen by the figure.

If the position of the capital of a work be required.

Take the mean bearing of the faces and move along the front until the opposite angle is the bearing of the salient. For instance, the bearing of face x, Lunette III., is 70°, that of face y 300°. $\frac{300 + 70}{2} = 185°$. The line L bisects the salient angle, being found by moving across the front of the work until its salient bears 5°, the opposite angle to 185°.

The early morning or evening are the best times for making these observations, as the various lines of parapet can be made out, being alternately illuminated or in shadow.

PROBLEM VII.

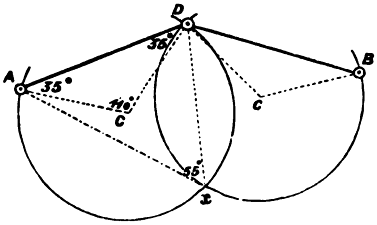
WITH SEXTANT.

To find the spot on the sketch corresponding with one's position on the ground.

The spot can be found by interpolation with the Prismatic compass, by observations of two visible Stations, as shown Page 36, but for the Sextant three Stations must be visible.

The problem is derived from Euc. III. 20, upon the same base the angle at the centre is double that on the circumference.

Let A, D, B, be the three Stations the position of which has been fixed on the sketch, and that it is required to find the position of x.



Observe the angles A x D, D x B, 55° and 62°.

x is on some part of the circumference of a circle, the angle at the centre of which subtended by A D is double 55° (or 110°). And of another circle, at the centre of which the angle subtended by D B is double 62° (or 124°).

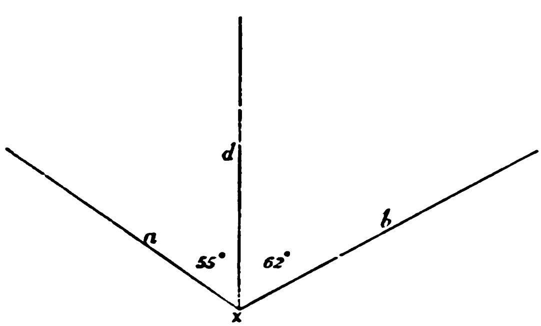
Then to find the centre of the circle A D x. The angles C A D, C D A, being together 180° − 110°=70° each of them is 35°. Lay off this angle at A and D, the centre is at the intersection C. Describe the circle.

In the same manner, to find the centre of the circle DxB; lay off at D and B $\frac{180-62}{2} = 29^\circ\ 30'$, x is determined by the intersection of the two circles.

When the observed angle is greater than 90°. The centre of the circle will be at the far side of the line joining the Stations. To find it, make the calculation as above for the supplement of the observed angle. Thus if the angle were 117°, the calculation would be made for 180 − 117 = 63°.

The point may be quickly found by laying on the sketch a piece of transparent paper, whereon the observed angles are laid down, and shifting its position until these lines coincide with the Stations. Thus with reference to the preceding Fig., the observed angles being A x D 55°, D x B 62°.

Draw a line dx and lay down these angles on each side.



By applying this so that the points A, D, B, may be under the corresponding lines a, d, b, the point x may be found and pricked through.

Problem VIII.

This Problem does not form part of the course.

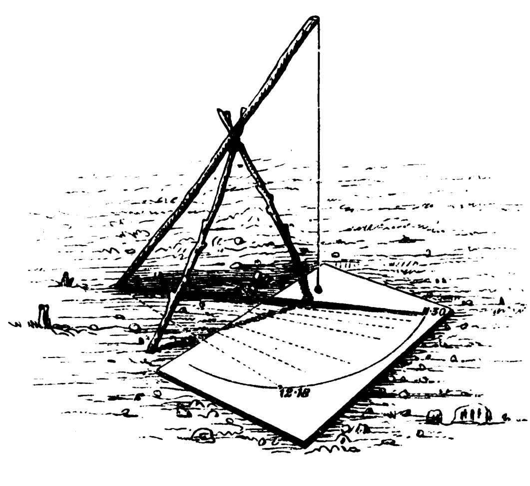
To correct the time without instruments.

To those who may be in districts remote from civilization for some time on shooting excursions, &c., the following system will be found useful.

As the sun reaches its highest point in the heavens at noon, the shadow which an object will project at that moment will be at its shortest.

If it were practicable to plant a staff vertically in the ground in a level spot, and ensure its immobility for half an hour or so, the moment at which its shadow is shortest might be observed by marking arcs, with the length of the shadow as radius, and the foot of the staff as centre.

But as it is a tedious operation setting a staff truly vertical, and it cannot be depended on to remain so, I recommend the following plan. About half-an-hour or so before noon, stick



any pole about 6 feet long lightly into the ground, pointed in a southerly direction, and supported by two cross sticks lashed together, as shown. Its immobility may now be depended on.

Mark the end of the shadow, and write down the moment according to the watch you wish to correct.

Then find a point vertically under the top by a bullet and thread. With this point as centre, and the distance to the point where the shadow was marked as radius, describe an arc.

When the shadow, after getting shorter and shorter, again lengthens until it reaches the arc, take note of the moment.

The sun will have culminated in the heavens meantime between the occurrences noted.

The first time was say 11.30, and the second 12.18, accord· to the watch. The interval between them being 48 minutes, noon really occurred 24 minutes before the last observation, instead of 18, as shown by the watch, therefore the latter is 6 minutes too slow.

The leaf of a camp table placed level upon the ground enables the experiment to be more accurately performed.

Stick a pricker in the table for centre, and use a pencil to describe the arc, for which purpose a twig with two notches cut in it at the required length is better than a string.

SECTION XV.

RECONNAISSANCE.

In order that any operation in war may be undertaken without hesitation, and performed rapidly, the leader must be well acquainted with the scene of action, its resources and manœuvring capabilities, the number and condition of the roads by which he can advance, the position and strength of the enemy, and a variety of other information which he can only obtain by deputy. It would be superfluous to enlarge upon the responsibility resting on officers chosen to collect this intelligence under circumstances of difficulty and danger, and on the necessity of bringing to the task powers of observation, highly trained and practised in time of peace.

The Government maps, though available alike to, and freely used by both sides as strategical plans, give only a small portion of the information required for tactical guidance. Intelligence as to positions suitable for defence or encampment, the extent to which the configuration of the ground will affect movements of the different arms, the state of the railways and of the rolling stock available, the disposition of the people, and so forth, can only be given by sketches and written reports made at the time.

By habituating himself to weigh the tactical value of objects on every occasion, an officer will acquire the *coup d'œil militaire*, the faculty of rapidly grasping the situation, which, with a clear, concise method of conveying his impressions to others, is essential in reconnaissance.

Reconnaissances are made either in force or secretly. In the first case the enemy will be in position, and will have covered his front with outposts, whose business it will be to prevent his dispositions being discovered. A reconnaissance in force may then be necessary, an attack made in sufficient strength to drive back his pickets, and cause him to show his dispositions to some extent. The leader endeavours to gain his object without committing his force to a serious engagement, but instances are frequent in which such a reconnaissance has led to a general action, either from the attacking party having become inextricably engaged,* or from some such important temporary advantage having been gained as appeared worth following up. Staff officers, on these occasions, penetrate to the front as far as possible, and trust to their powers of observation and memory to collect information, but as it would be impracticable to sketch or take measurements, no more need be said of the subject here.

Again, if the enemy is close at hand, an officer will endeavour to gain information by stealing as close to his outposts as their want of vigilance will allow, but he will not usually be able to sketch or take notes.

If the opposing forces are at a few days distance apart, and (as often happens) are racing for a certain important point, each trying to interrupt or delay the other's progress by blowing in tunnels, breaking up railways, &c. ; or if penetrating into an unknown country ; on these and similar occasions, the services of specially qualified officers are indispensably necessary to feel the way in advance of the army.

Though some knowledge of tactics is required, the subject is avoided here as beyond the limits of these pages.

It is unnecessary to lay down rules here as to the steps the officer should take to provide for his safety ; the work

* It is supposed to be more difficult to break off an action now than formerly.

will generally be attended with great personal risk, and his escort must be so disposed as to secure him from surprise.

ROAD RECONNAISSANCE.

THE REPORT.

A few of the points to which attention will be directed are:—

Roads, their condition and material, width, how fenced, liability to get out of repair and means of repairing; practicability for all arms; contractions at bridges and other narrow places; possibility of moving troops across country parallel to the road; positions for defence in case the march should be opposed; the gradients, 4° will delay baggage-waggons considerably, 8° will be insurmountable to them, but artillery can ascend a much steeper slope. All defiles through which the road passes are described, woods, bogs, hills, &c.

Rivers. Their average depth, width, and rapidity, liability to floods, possibility of inundating the country by damming; the height and nature of the banks, and their command over each other.

The existence of fords is to be carefully sought for, the indications vary in different countries, but will always strike a shrewd observer, such as cart or cattle tracks ending abruptly at the water's edge. A ford will seldom be straight across stream; the nature of the bottom should be examined and reported on, gravel is most durable, mud will become too soft, sand when disturbed washes away, and the ford soon deepens.

The depths at which a ford is passable for the different arms, with a moderate current, are about, Cavalry, 4 feet, Infantry, 3 feet, Artillery, $2\frac{1}{2}$ feet. If the stream is rapid, these depths would be too great; if sluggish, and with a firm and smooth bottom, they may be greater for infantry carrying their ammunition in their hands. Guns with the ammunition removed from the limbers, may be dragged across by ropes.

To find the existence of fords in deliberate reconnaissance, when a boat can be obtained, drop down mid-stream with a pole lashed to it at the required depth, whenever this touches bottom, examine the locality.

To find the rapidity. The current will be greatest about the centre, and is not uniform at all depths, as friction against the bottom retards it. As good a way as any is to throw into the stream a bough of a tree, the branches of which will penetrate some way below the surface; time its passage between two marks on the bank at a measured distance of 200 or 300 yards. When there is any question of its being more than sluggish, it is better to give the actual velocity than to use the terms "moderate," "rapid," &c.

Boats must be sought for and their capacity noted. Particular attention will be paid to the bends of the river, with a view to the tactical advantages of those salient towards the observer, and *vice versâ*.

Bridges. Their material, height, width, number of arches thickness of piers and crown, facilities for destroying or repairing.

Woods. Their extent, density, and the species of trees. The underwood is of the greatest importance, as affecting their penetrability. An extensive and dense wood may be best surveyed by traversing round the outskirts, as it is impossible to preserve a line of direction through it. Both the position and size of smaller groups of trees may be fixed in the sketch, by taking bearings of their edges from a distance from different directions.

Railways. Reports on railways are generally made under two headings.

1st. Considered as simple roadways, and with reference to the facilities for marching troops thereon.

2nd. Considered as to their capacity for transporting troops, stores, &c., by steam.

Gauge, double or single line, how ballasted, the embankments, cuttings, bridges, and tunnels; facilities for destroying by blasting or otherwise; number of telegraph wires. Stations, size of platforms and convenience for loading trucks with artillery and cavalry; amount of rolling-stock available, and the capacity of the carriages and trucks; forges, stores of platelayers' and excavators' tools, spare rails and sleepers, telegraph wire, fuel, &c ; number of employés.

Positions. All important positions should be separately sketched on a larger scale (usually six inches to a mile) and reported on.

Fences. Whether slight and easily levelled as posts and rails, thin hedges, &c.; or affording ready-made breastworks, such as banks and ditches, and the effect they would have upon the movements of troops.

Mountains and Hills. Whether practicable for all arms, and large bodies of troops; whether a good view can be obtained from their tops; whether they are bare or covered with woods, &c.

Villages and Hamlets. Their material and suitability for defence; shops and stores.

It would be unnecessary further to enumerate the objects to which, under various circumstances, attention will be directed, the tactical importance of *everything* within view must simply be taken into consideration.

An officer making a reconnaissance on service, will be pressed for time, and will not have opportunity to do more than guess at the details of accommodation, population, resources, &c., for which there are columns in the tabular forms provided for reports (which as a rule are much too elaborate for service). When he is unable to collect exact information on these points from local officials, he should state that such is the case, and that the statistics given are only roughly approximate. In most districts, five inhabitants to each house will be nearly the population.

In India it is unnecessary to give the population of towns or villages, as they are unsuitable for occupation by Europeans.

A simple form of report is shown in Plate XIV. With us the entries in the report at present range with the sketch (from the bottom of the page upwards), which is supposed to facilitate their comparison; but the last column of "Particulars," which in our forms is headed "General Observations," may be written in the ordinary sequence, as in Plate XIV.

When it is intended to occupy a district for a period, the reconnaissance takes the form of a carefully-compiled statistical report of the resources of the country, the number and description of cattle, farm stock, and crops. Population, trade, shops, &c. This work can only be performed at leisure.*

In taking notes in the field, it will only be necessary to enter particulars, such as dimensions and numbers, it would be waste of time to write general descriptions with which the memory may be trusted.

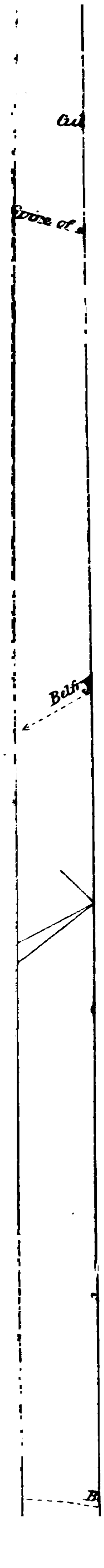
Two or three pages of a tolerably large note-book should be prepared with the form of report.

Objects not identified by names, such as bridges, &c., must be numbered to correspond in the sketch and report.

The fair copy should be made out as early as possible, whilst the impressions are fresh in the memory.

The terms "right" and "left" are only to be used in describing rivers, ravines, &c., the observer being supposed

* The reader is recommended to refer to General Napier's "Outpost Duty, Reconnaissance, &c.," in which forms of report are given.



to face down stream. In all other cases the terms "east," "west," &c., are used, as being less liable to misinterpretation.

The report should be as brief as possible, whilst omitting nothing really important, whatever can be explained by the sketch, it is unnecessary to mention in it, and *vice versâ*.

It is most important that the writing should be clear and legible.

The effect of slopes upon the different arms, when moving straight up hill, is stated as follows in the Aide Memoire.

60° Inaccessible for infantry.
45° Difficult.
30° Inaccessible for cavalry.
15° Inaccessible for artillery.
5° Easy for artillery.

These rules are very general ; the limits of accessibility are affected rather by the nature of the surface than by the inclination of the ground.

The instructions, in compliance with which the reconnaissance is made, should be quoted or attached to the report.

THE SKETCH.

The sketches accompanying the reports in road reconnaissance, are usually made at the scale of two inches to a mile.

The general direction of the line to be followed being ascertained, the meridians should be ruled on the paper in such a direction as will admit of the road being drawn from the bottom upwards, and in the centre of the sheet.

On first commencing road reconnaissance, the officer having probably been accustomed to draw on a larger scale, will be apt to enter into detail somewhat minutely, and will find that his progress is too slow, and that confusion arises from his trying to represent too much. Working on so small a scale, he must trust to the eye rather than to actual measurements, except as regards the forward distances which must be quite accurate.

In this, as in all military surveying, he should work against time, remembering that on service he will be liable to interruption, and that every minute will be precious.

If the country is open, and the objects of tactical importance few, the sketch should be done on horseback, a scale suitable for the trot or canter having been prepared; but when it is required to use the compass, time is saved by dismounting, however steady the horse may be. The advantage gained by working on horseback, is not only increased power of locomotion, but also range of observation. No finished drawing need be undertaken in the field, but the work should be clear and intelligible ; coloured pencils are very useful, one with blue and red at opposite ends should be provided to distinguish water and buildings. The paper should have a very smooth surface.

The country on each side, at least within range, should be represented, and the bearing of important places laid down, although they may fall beyond the limits of the sketch.

The surveyor seldom leaves the road, but from thence sketches the adjacent country within about half-a-mile, estimating the distance of villages, houses, &c., when they are in a direction perpendicular to the forward angle. If he is mounted, he must be provided with a scale of yards, as well as of horses' paces, so as to be able to draw objects at their estimated distances.

Objects at a greater distance than about half-a-mile should be fixed by intersection (Page 45).

If the road winds much, it will be only necessary to take the bearings of the longer reaches, the others can be drawn with sufficient accuracy by considering the angle they form with these.

Care must be taken not to lose count of the number of yards or horses' paces. When a halt is made to sketch or take an observation, their number should be written down. After a little practice one should be able to show offset objects at their estimated distance without using a scale, but the forward distances must be carefully laid down to scale.

Attention must not only be directed to what is close at hand; the general distant direction of streams, roads, &c., which are crossed should be made out, the lie of the country will show the former, or willows growing on the banks, bridges, the gleam of water, &c. Distant houses, enclosures, walls, &c., should be examined with field glasses.

A railroad is generally a good line to traverse when sketching on foot, as it runs in cleared ground, has few curves, and from the embankments a good view may be obtained.

If a road or river runs somewhat parallel to the line traversed, as in Plate XIV, they may be sketched simultaneously, the distance of the second being judged occasionally, or obtained by intersecting trees, houses, &c., upon it.

As to the representation of hills. Neither the scale of horizontal equivalents, nor the scale of shade, would usually be suitable at so small a scale as two inches to a mile* (Note, page 57, 66). They may be drawn on the horizontal system, with a more minute hâchure, if necessary, than that of the scale of shade, or by contours representing any convenient vertical interval: in either case, the approximate heights should be figured on the sketch. No great accuracy is expected in the representation of the minor features, it will be sufficient if a correct idea of the general form and position be given.

* The copy of the ground represented in Plate XIV has been made on the present system of horizontal equivalents, as the features are large, and there is so great a difference of level as 300 feet.

Sketching a road in level country is a very simple matter, which an officer should be able to perform well after a few days' practice.

The rate of working will vary according to the nature of the country, from one to three miles an hour (the latter on horseback).

If it be desired to make a fair copy of the sketch, the quickest and easiest way is to fasten them together, and trace through against a window or a tracing-frame. If the original be very faint, or the paper thick, the tracing may be done by black transferring paper, but this defaces the original. "Pricking through" is tedious, and also defaces the paper. The system of squares (page 11), would generally take too much time.

SKETCHING POSITIONS.

Beginners generally construct a triangulation as the first step in sketching a portion of country, this necessitates going over the same ground twice, and takes much time.

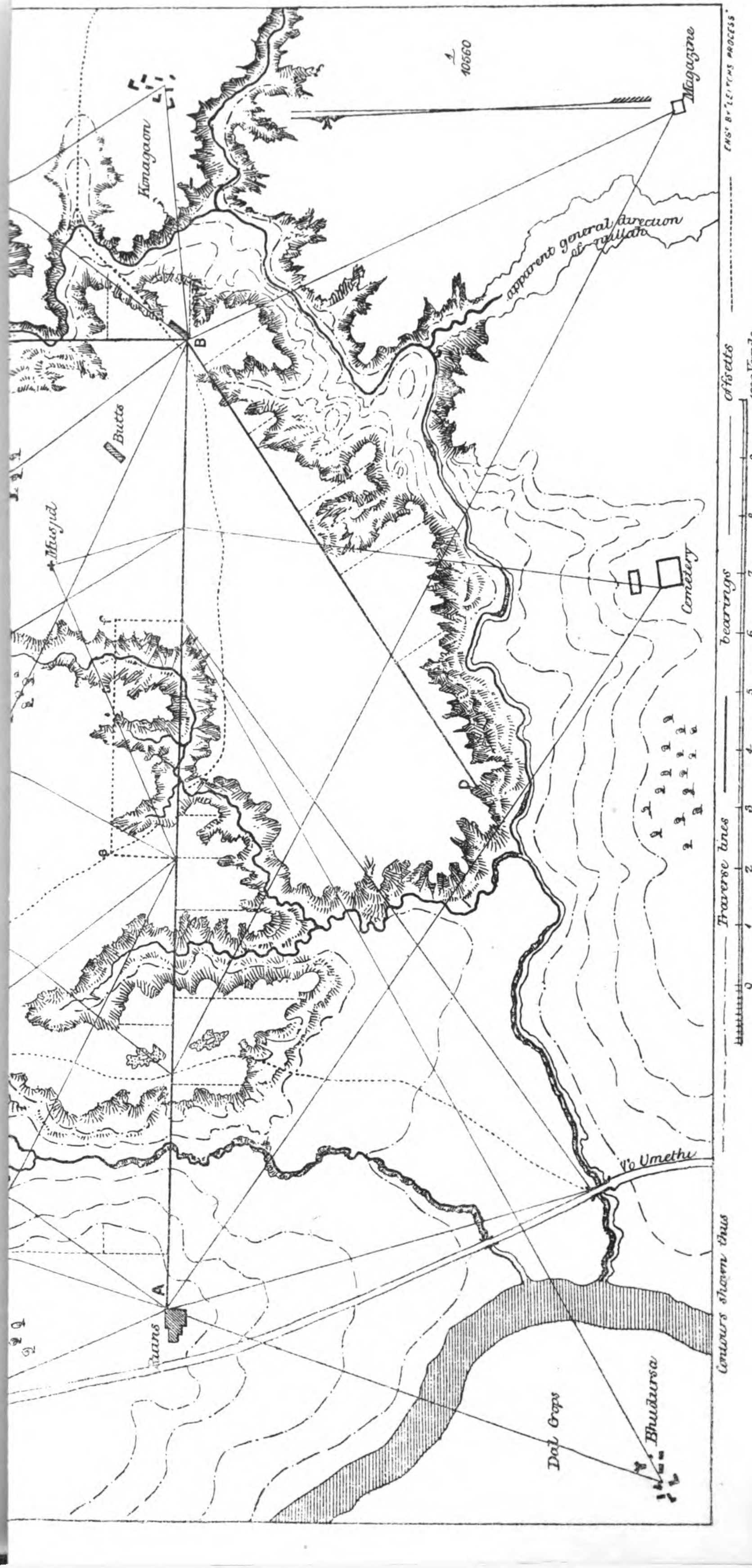
After accuracy and certainty have been gained by practice, the regular triangulation may generally be dispensed with, and the operations of sketching near objects and determining the position of distant ones, carried on simultaneously.

This method (Plate XV), is particularly suited to an open country. In closely-fenced ground, it will be difficult to depart from the system of first establishing a triangulation.

As in sketching without instruments, judgment and care are required, 1st, to work upon none but long traverse lines, 2nd, not to lose count of the paces, and to mark the place on the ground to which one must return after offset measurements.

As the offsets will often be long, other measurements may again be made perpendicular to them when necessary.

It will be observed that in pacing A B, it was necessary to


1/10560
Magazine
Konagaon
apparent general direction of nullah
B
Butts
Musjid
Cemetery
A
To Umethi
Bhudursa
Dal Crops
Contours shown thus
Traverse lines
bearings
Offsetts
Scale - Six inches to a Mile
1000 Yards

diverge and measure e f parallel to it, in order to avoid bad ground.

The sketch was commenced at A, and traverse lines paced to B, C, and D, distant objects being intersected as they became visible, by a "running triangulation." It then only remained to ride round to a few of these distant points, and sketch the vicinity.

The report on a position will be drawn up under the following headings :—

1. Communications.
    a, to front and rear.
    b, lateral.
2. Breadth and depth of position.
3. The flanks.
4. The nature of the surface of the country.*
5. General observations.

The report is to be made out on quarter margin foolscap paper, with the above headings marginally noted. Whilst as condensed and brief as possible, it should describe particulars which are unexplained by the sketch, and also furnish some information concerning the country in the vicinity, such for instance as the facilities offered for effecting turning movements unobserved, or the existence of a second position in rear where a rally might be made.

Recommendations as to the manner of occupying the position should not be offered uncalled for, but the officer may have to furnish his views on this subject, and on the strengthening of the position by field works, the probable manner of the enemy's attack, &c.

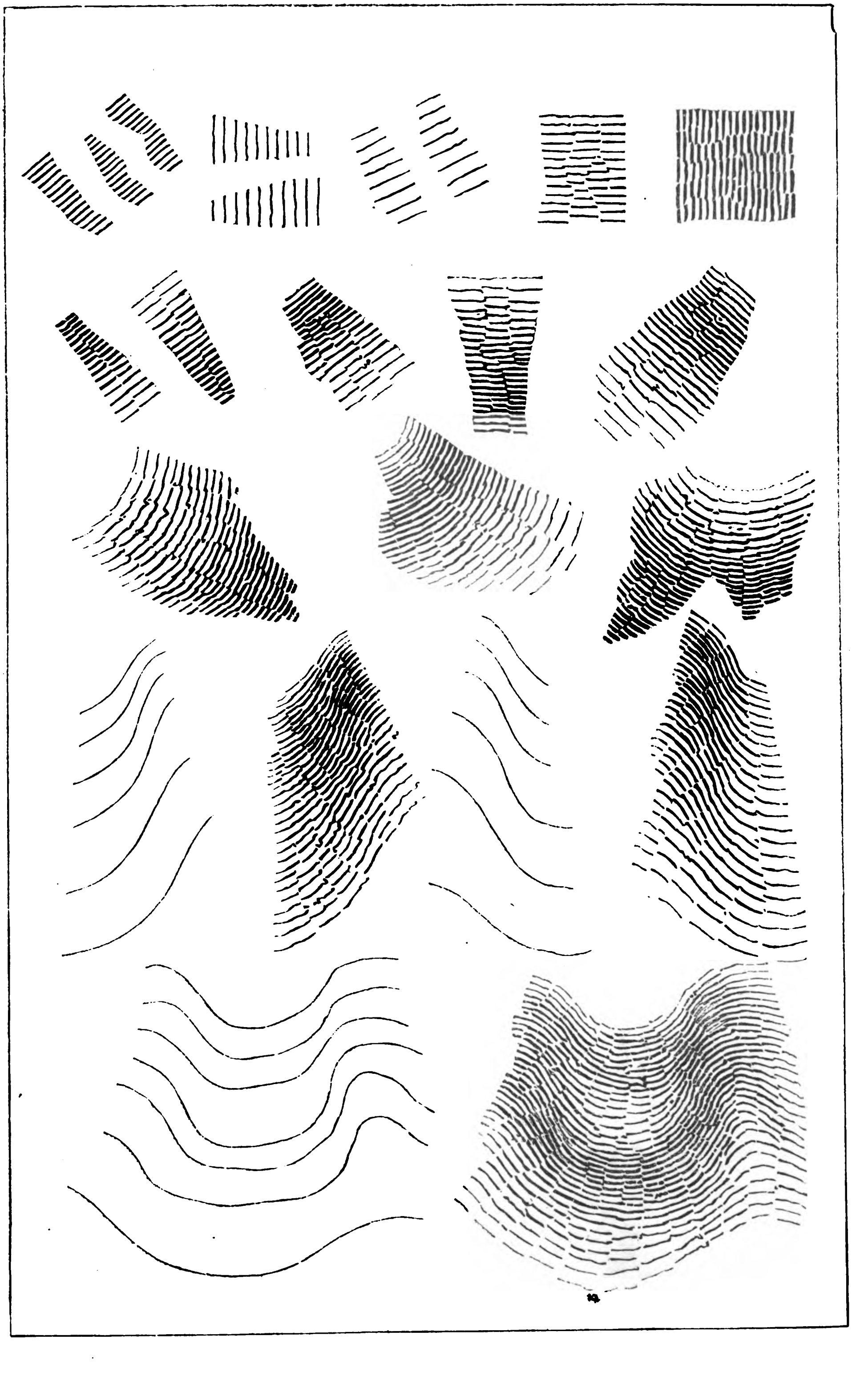
Study of tactics is required, to enable an officer rightly to judge of the suitability of a position for the required purpose.

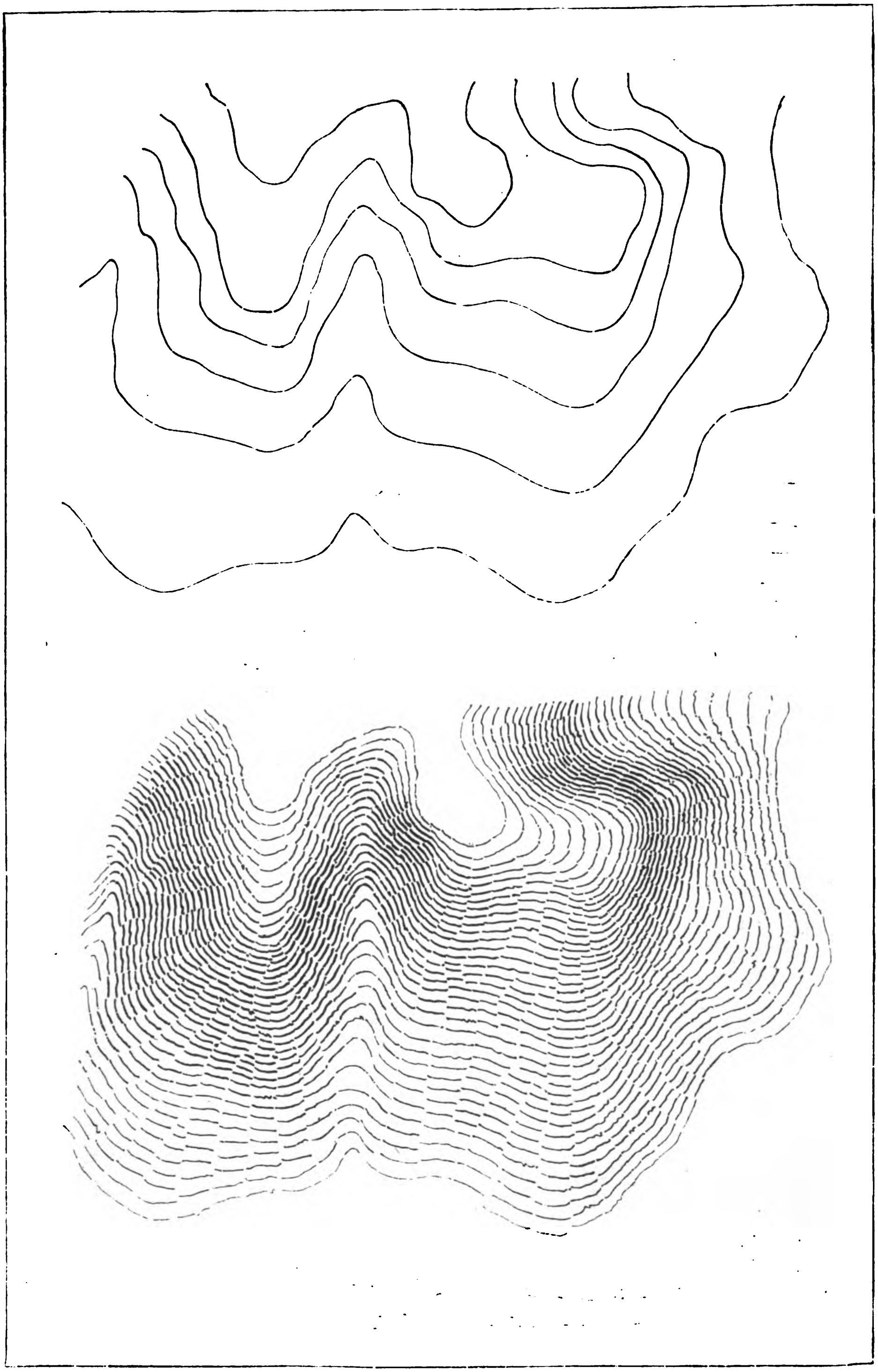
* Particularly with reference to the effective use of the three arms.

It must be well adapted for the effective employment of the arm in which the defenders are strong, and must be of extent proportionate, to their numbers; from 15,000 to 20,000 men per mile of front, is generally accepted as the proper proportion with reserve, but it is impossible to lay down precise rules on this subject based on past events, for whilst the reader will call to mind many great battles in which these numbers have been exceeded, the defensive power of the breech-loader has of late permitted good positions to be held with a weaker force. The investment of Metz and Paris, and the events of Sedan, are in a great degree explained by this attribute of modern fire-arms.

About one-third of a mile, at least, is necessary in depth to allow of lateral movements, and to give room for the second line and reserves.

London:—WM. H. ALLEN & Co., Printers, 13, Waterloo Place, Pall Mall. S.W.





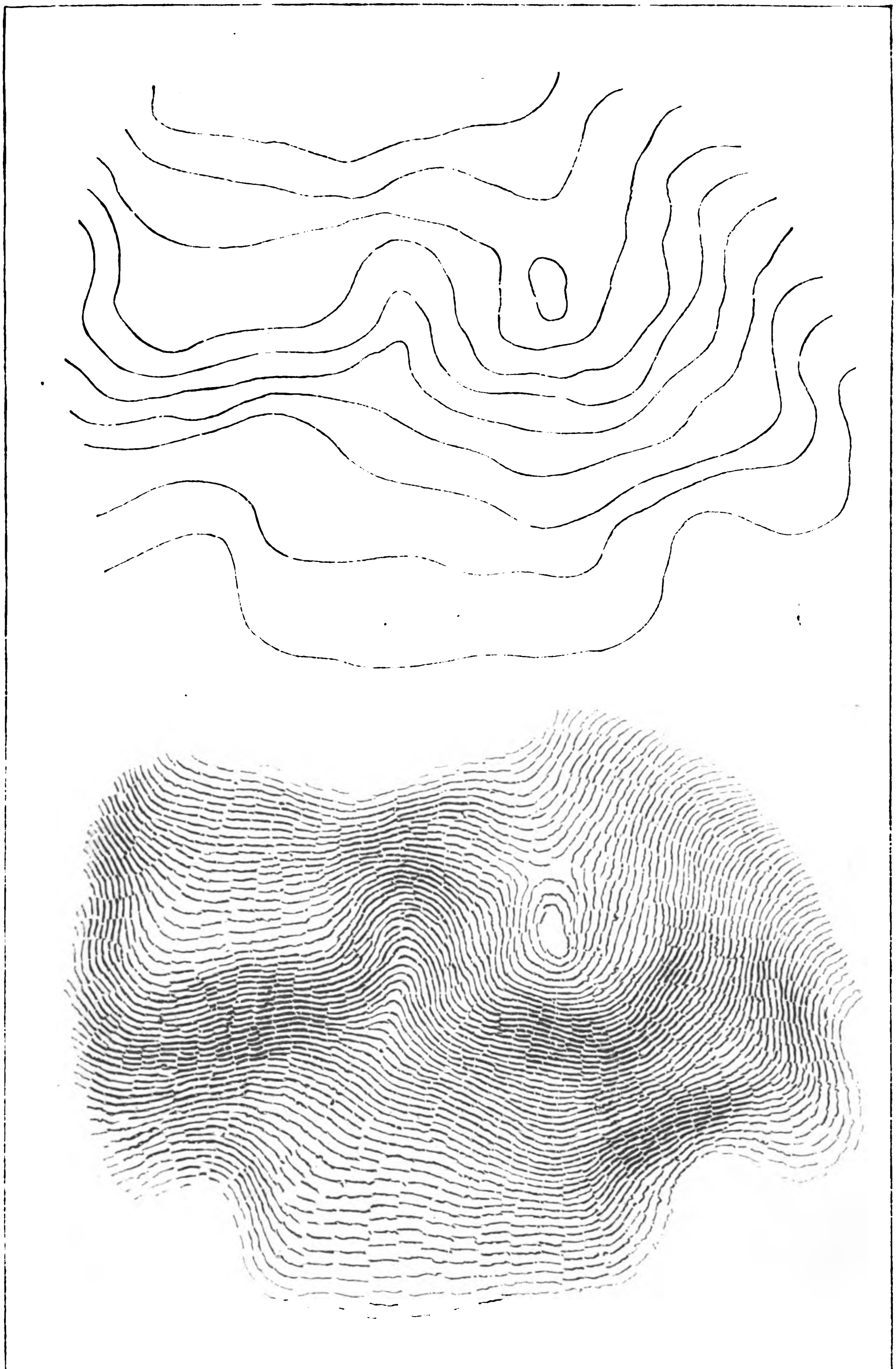


PLATE XIX,

MILITARY SKETCH.

Scale 6 inches to 1 Mile.