MANUAL OF MAP READING PHOTO READING AND FIELD SKETCHING 1929

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MANUAL OF MAP READING, PHOTO READING, AND FIELD SKETCHING

1929

THE WAR OFFICE

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TABLE

MANUAL OF MAP READING, PHOTO READING, AND FIELD SKETCHING

INTRODUCTION

1. The Scope and Intention of the Manual

This manual is intended for the use of candidates for commissions in the Regular Army and in the Royal Air Force, and also for the instruction of officers and non-commissioned officers. Its object is to provide instruction in the use of maps and photographs, and in the making of sketches.

These subjects are necessary items of military education and aim at enabling the student to visualize, appreciate, and make good use of, the tactical features of the ground.

2. Field Sketching

The importance of Field Sketching for commissioned ranks cannot be over-emphasized. The facility for neatness and accuracy, acquired under a good system of instruction, will prove of value in practically every branch of the military art. There is no better method of developing an eye for country than the practice of careful field sketching.

3. Map Reading

Map reading offers no difficulty to those who have learnt to sketch. It is, however, impossible to base the instruction of the recruit upon sketching, and map reading must be taught separately. The first part of this Manual is therefore reprinted with certain appendices, under the title "Notes on Map Reading," and will be used in connection with examinations for certificates of education.

4. Air Photo Reading

The air photograph is of increasing value in studying ground to be fought over and will often be used in war to amplify the map and to discover hostile battery positions, entrenchments, and other ground organizations. With the help of a simple stereoscope, relief can be studied, and an easy method is afforded of instruction in contours.

5. The Arrangement

In framing this edition the guiding principles have been to include all that is essential, to omit all else, however interesting, and so to arrange it that the first part may be printed separately as a complete treatise on map reading.

The subjects included in the 1921 edition, and now omitted, include the tactical side of military reports, lists and samples of British and Foreign maps, map projections and land forms. On the other hand, more space is devoted to the use of air photographs, and to foreign conventional signs and systems of reference. Instruction based wholly upon maps of Great Britain cannot be considered satisfactory for an army which has to use, even for training, so many different kinds of maps.

PART I-MAP READING

CHAPTER I

INSTRUCTION IN MAP READING

1. The Object of Map Reading

The study of map reading must start with a general statement of the object in view : for map reading is not an end in itself.

As it is seldom possible to inspect the ground on which movements will be carried out, or to remember accurately details of such ground once seen, some representation of the area involved must be prepared. This is called a Map.

The object of map-reading is to render possible the clear and accurate visualization of the ground.

2. The Progressive Steps in Instruction

To reach that standard the student must be taught to master:-

Chapter II. The names by which the ordinary features of the ground are known, and what meaning to attach to the special expressions and terms used.

- III. How to measure or estimate distances on the map.
 - IV. By what signs, or symbols, objects are shown on the map.
 - V. How to visualize hill and valley from the contours, and to estimate the intervisibility of points.
 - VI. The difference between true, magnetic, and grid north.

VII. The object and use of a map reference.

VIII. How to set a map and find position upon it.

IX. How to enlarge a map.

X. How to use a prismatic compass and protractor.

3. Maps Generally

It must be remembered that no map can be perfectly accurate and no map can show more than its scale permits. Even maps of Great Britain, which are as good as possible, are only issued in a revised form every fifteen years and the constant alterations and additions in a highly civilized area soon render the best work out of date. The fact that the major portion of the British soldier's instruction will be based on Ordnance Survey maps should not be permitted to lead to an appreciation of Ordnance Survey methods and symbols only.

Constructive common sense and not slavish imitation is the goal to be reached.

Since the "man-in-the-street" is not a qualified map reader, much information is always included in the margin of a map and the student should be trained to make full use of the data thus supplied and to know where to look for the following information:—

i. What locality it deals with.

ii. Its scale.

iii. Its orientation, and the local magnetic variation (north point).

iv. The conventional signs it employs.

v. The contour system and interval.

vi. The date of issue or revision.

vii. By whom and how it was made.

viii. The system of reference and grid employed.

ix. The names and numbers of adjoining sheets.

Whilst studying each point the student should study how the map itself explains it, and gain the habit of looking at once to the proper place for the information he requires.

4. Map Marginal Lines

In the course of his service a soldier will deal with all sizes and shapes of map. The only point of consequence in those differences, which do not affect the picture of the ground, is the curved (graticule), as opposed to the rectangular (grid), shape of the bounding lines of some maps. The difference is clearly brought out in Plate I, and should be explained with particular reference to the use of true and grid norths. The practical advantages of a grid for references and for the work of surveying and mapping in the field may here be explained. The maps of Great Britain and of India are the obvious examples to use of rectangular and geographical sheets respectively.

Such possibly interesting but unessential points as the position of the origin or the type of projection should form no part of the instruction.

5. Instruction Indoors

The practical application of map reading should be emphasized throughout.



PLATE I.



works of man-towns, villages, roads, canals and railwaysshould come last. The aim of instruction should be to train the mind to form, from a map, a correct mental picture of the country, and to estimate the amount of cover and of tactical difficulty which it is likely to offer. If maps of two different scales are available, a comparison between them. and between each and the country, will explain the amount that a map can show on these different scales. Ultimately it is the standard map, the one inch (abroad the 1/50,000 or 1/100,000), which is the most important. However expedient it may be to start the recruit upon a large scale (say six-inch or three-inch), it must be remembered that the rank and file will see few such maps in war. The large scale will seldom be issued in quantity, except during periods of comparative stability, and the small scale, which might be widely used in uncivilized or poorly mapped theatres of war, will not be the normal issue for operations or training in a civilized country. It is, however, important to explain how all scales can be read and reference be made to them in the light of a common

CHAPTER II

DEFINITIONS

8. Topographical Forms

- Basin.—(a) A small area of level ground surrounded or nearly surrounded by hills, and (b) a district drained by a river and its tributaries, e.g. the "basin of the Thames."
- Col.—A neck or ridge of land connecting two mountains or hills. A col is lower than the mountains or hills it connects, and higher than the surrounding plain or valleys.
- Crest.—The general line formed by joining the summits of the main ridge of a chain of mountains.

False crest.—The line along which a lower steep slope changes to an upper gentle slope.

Dune.-A hill or ridge of sand formed by the wind.

Defile.—Any natural or artificial feature which causes a body of troops to contract its normal front during its passage through it, is a defile for that body. A mountain pass is the most common type of natural defile; a bridge, or a raised causeway through a marsh, is an example of an artificial defile. Estuary.-The tidal mouth of a river.

Escarpment.—An extended line of cliffs or bluffs.

Foreshore.—That portion of the shore between high and low water at maximum spring tides.

Gorge.-- A rugged and deep ravine.

Knoll.-A low detached hill.

Main feature.—Those important forms such as ridges, drainage systems, etc., which determine the shape of the country (sometimes called salient features).

Pass.-A road or track over a mountain range.

Plateau.—An elevated plain.

Re-entrant.—A re-entrant occurs where the hillside is curved inwards towards the main feature ; it is always found between two salients.

Saddle.-A col.

Salient or Spur.—A projection from the side of a hill or mountain running out of the main feature.

Underfeature.—A minor feature; an offshoot of a main feature.

Undulating ground.—Ground which alternately rises and falls gently.

Water-course.-The line defining the lowest part of a valley, whether occupied by a stream or not.

Watershed.—A ridge of land separating two drainage basins; the summit of land from which water divides or flows in two directions. A watershed does not necessarily include the highest points of a chain of mountains or range of hills.

This list does not profess to be exhaustive ; there are many common words such as hill, mountain, river, slope, island, cliff, ravine, etc., which it is unnecessary to define.

9. Technical Terms

Bearing .-- True bearing is the angle a line makes with the true north line.

Magnetic bearing is the angle a line makes with the magnetic north line.

Grid bearing is the angle a line makes with the grid north line.

All bearings are measured clockwise.

Contour.—A contour is an imaginary line on the surface of the ground at the same height above mean sea-level throughout its length. Contours may also be defined as the plans of the lines at which a water surface (of the ocean, for instance) would intersect the surface of the earth were it raised successively by equal amounts.

- Contour Interval.—The difference in level between two adjacent contours (generally known as the Vertical Interval).
- Datum or Datum Level.—The level to which altitudes are referred.
- Detail.—All minor natural or artificial features of the ground or on the ground.
- Fall of a River.—Its slope, usually measured in inches (or feet) to the mile, thus: 9 inches to the mile.
- Fixed Point.—A point is fixed when its position is known and can be plotted on paper in correct relationship to other points.
- Form Line.-An approximate contour; a sketch contour.
- Gradient.—A slope expressed by a fraction. Thus 1/30 represents a rise or fall of 1 foot in a distance of 30 feet.
- Graticule.—A system of four-sided figures formed by lines which represent portions of meridians and parallels.
- Grid.—A system of squares formed by lines which represent progressive distances east and north of a fixed origin.
- Grid North.—The lines of a grid point nearly, but not quite, north and south, and nearly, but not quite, east and west. Those which run nearly north and south are Grid North lines.
- Hachures.—Vertical hachuring is a conventional method of representing hill features by shading in short disconnected lines drawn directly down the slopes in the direction of the flow of water on the slopes.
- Horizontal Equivalent (usually written H.E.).-Is the distance in plan between two adjacent contours.
- Latitude.—The latitude of a place is the arc of the meridian from the place to the equator, expressed in degrees at the centre of the earth.
- Local Magnetic Attraction.—Is the deviation of the magnetic needle of a compass from its mean position, owing to the presence of masses of magnetic iron ore or of iron in the neighbourhood.
- Longitude.—The longitude of a place is the angle at the pole between the meridian of that place and some standard meridian (generally the meridian of Greenwich).

It is called east or west variation according as to whether the magnetic north is east or west of the true north.

Meridian or Meridian-Line .- A true north and south line.

Magnetic Meridian.- A magnetic north and south line.

- Orienting or Setting a map, plane-table, photograph, etc., is the process of placing it so that its true north line points to true north.
- Plotting.—The process of recording on paper field observations and measurements.
- Ray.—A line drawn from the position of the observer, to represent the direction of an object.
- Resection.—A method by which the position of the observer is determined by observing the bearings of or drawing lines from at least two previously fixed points.
- Section.—The outline of the intersection of the surface of the ground by a vertical plane.

Setting a map.—See Orienting.

(Sterl

True North at a point is the direction of the North Pole from that point.

Vertical Interval (usually written V.I.) is the difference in level between two adjacent contours.

CHAPTER III

SCALES AND UNITS

10. Definition of Scale

The word "Scale" means the proportion which the length between any two points on a map (sketch or photograph) bears to the horizontal distance between the same two points on the ground.

Thus if the length between two farmhouses on the map is one inch and the horizontal distance over the ground is two miles, the scale of the map is one inch to two miles.

The word "scale" is also used to denote a line drawn on the map and suitably divided so that measurement of distance can be made, with its assistance, on the map in question.

11. Methods of Expressing Scale

1. The scale may be described in two ways-

- i. In words showing the relation between any unit on the map and any other on the ground.—As the inch is the unit by which the eye judges small distances, and distances are generally given in miles, English scales are generally made to show a certain number of "inches to the mile" or "miles to an inch." The statement is usually in miles to one inch for the one inch and smaller scales : whereas it is usually in inches to the mile at scales larger than the one inch. Maps of countries which use the "metre" are, however, generally made to show a certain number of centimetres to a kilometre.
- ii. By the Representative Fraction (commonly known as the R.F.), which expresses the same relation in the terms of a fraction with "one" as numerator, the denominator being expressed in the same unit, e.g. 1/100. It is obvious that the relation expressed by the fraction remains unaltered whatever the unit employed may be.

The advantage of using the R.F. is that the relation in scale between maps which employ different units can be established at once (*see* example).

Examples.—The following examples explain the two ways of expressing scales :—

- Scale 1/63,360 or 1 inch to 1 mile. Here 1 inch on the map represents on the ground 63,360 inches, *i.e.* 1 mile.
- ii. Scale 1/100,000, or 1 centimetre to 1 kilometre. Here 1 inch on the map represents on the ground 100,000 inches=1.58 miles; or 1 centimetre on the map represents on the ground 100,000 cms.= 1 kilometre.

 Supposing that the R.F. alone is given, the number of "miles to the inch" or "inches to the mile" can be found in the following ways:---

- To find the number of miles on the ground corresponding to 1 inch, on a map for which the R.F. is given, divide the denominator of the R.F. by 63,360.
- To find the number of inches on the map corresponding to 1 mile on the ground, divide 63,360 by the denominator of the R.F.

Thus, if the R.F. is 1/80,000, by rule i. the number of miles to the inch is 80,000/63,360=1.26. And by ii. the scale in inches to the mile is 63,360/80,000=0.79. It is useful to remember that an R.F. of 1/1,000,000 (commonly written 1/M) is equivalent to 15.78 (or approximately 16) miles to an inch. A comparison then tells us at once that 1/250,000 is about 4 miles to 1 inch; 1/2M is about 32 miles to 1 inch; and so on.

12. Design and Division of Scales

It is usual on maps and sketches to define the scale in both these ways, and to add at the bottom a printed or drawn scale, divided to show distances in a certain unit.

The unit employed and the R.F. should be stated above the scale. Scales are usually, though not always, made to represent a distance which is a multiple of 10 or 100 units of measure, *e.g.* 100 feet, 50 yards, 80 miles.

A scale should usually be from 4 to 6 inches long, and the first thing to consider is how many tens, hundreds, or thousands of the unit of measure will take up a convenient length on the paper.

A scale should be divided so as to make the fullest and most accurate use possible of the map or sketch in question. A distance of 10 yards may be important on a sketch at 12 inches to the mile and, therefore, the scale should show divisions of 10 yards. Similarly divisions of 100 yards should appear at the scale of three inches to one mile. Generally speaking it is wise to divide decimally—*i.e.* into tens, hundreds or thousands —whether the unit employed is British or metric.

A scale may be divided into small divisions throughout its length, reading from a zero at the left end. A scale of this sort is often called "fully divided" and is troublesome to construct because of the number of divisions to make. A more common form, often known as "open divided," is divided into large divisions, sometimes called "primaries," one of which is subdivided into smaller divisions called "secondaries." The usual arrangement of the division of an "open divided" scale is shown in Figs. 1 to 5.

13. The Scales of the Service Protractor.

The Service Protractor (see Plate XV, Chapter X) shows scales of $\frac{1}{2}$ inch, 1 inch, and 2 inches to 1 mile; also scales for R.Fs. of 1/20,000, 1/100,000, and 1/250,000. Thus the normal scales of English and foreign maps can be drawn from the protractor.

Example.—To draw a scale of 4 inches to 1 mile to show divisions of 100 yards from the protractor. Here the most convenient scale shown on the protractor is that of 2 inches to 1 mile. The distances shown on this scale are twice those on the scale to be drawn. The scale is to be between 4 and 6 inches in length. On measuring off 4 inches from the



scale of inches on the back of the protractor and applying this distance to the 2 inches to 1 mile scale, it is found that 4,000 yards is the nearest convenient round number, which gives a length of more than four inches. Draw a line equal in length to 4,000 yards on the 2 inches to 1 mile scale; this line represents 2,000 yards on the scale of 4 miles to 1 inch. Divide this line into 4 equal parts, each representing 500 yards. This can be done by taking a measurement of 1,000 yards on the 2 inches to 1 mile scale. These are the *primary divisions* of the scale. Sub-divide the left division into 5 parts each representing 100 yards. These are the *secondary divisions*. The zero of the scale should be placed as shown in Figs. 1 to 5, and the primary and secondary divisions be numbered outwards from it.

Primaries should be chosen so as to show miles or kilometres in units, tens or hundreds, or yards, in thousands or five hundreds, according to the unit of measure shown and the size of the scale. Thus a scale of miles or kilometres should show primaries of miles or kilometres; a scale of yards or metres should show primaries of thousands of yards or metres for scales up to 1/31.680, and five hundreds of yards or metres for larger scales. Secondaries should show $\frac{1}{4}$ miles, twentieths of kilometres, or hundreds of yards. Military *sketches* can rarely be of sufficient accuracy to make it necessary to show smallersecondaries; these are, however, shown on the protractor, which may be used to measure distances on military *mafes*.

14. Construction of Scales

The following examples show how a scale may be constructed when no protractor is available :---

 Example 1.—To construct a scale of 4 inches to 1 mile to show divisions of 100 yards.

Here 4 inches represents 1 mile, or 63,360 inches. The R.F. is therefore 4/63,360 = 1/15,840.

The scale is to be between 4 and 6 inches in length; it will therefore show between 1 and $1\frac{1}{2}$ miles, say between 1,800 and 2,600 yards. Take the greatest round number between these limits, say 2,500 yards.

The length of the scale will then be-

 $\frac{2,500}{15,840}$ yards $=\frac{2,500 \times 36}{15,840}$ inches =5.68 inches.

If it is preferred, the result may be obtained from a sum in proportion, thus-

Yards in a mile.		Yards in the scale.		Inches repre- senting a mile.		Length of scale in ins.
1,760	:	2,500	-	4	:	" x "
		Therefo	ore x	=5.68 inches.		

The length of a scale should be calculated to the second decimal of an inch, or the first of a millimetre.

Draw a line 5.68 inches long and divide it into 5 equal parts, each representing 500 yards. Sub-divide the left division into 5 parts, each representing 100 yards, as shown in Fig. 1.

Example 2.—To construct a scale of 1/100,000 to show auarter miles.

Here 1 mile is represented by 1/100,000 mile=63,360/100,000inch=0.634 inch. Hence, if the scale is to represent 10 miles in all, its total length will be 6.34 inches.

With the dividers bisect the total length of 6.34 inches, and divide each half into five. The primary on the left will be sub-divided into 4 secondaries, each representing $\frac{1}{4}$ mile. (Fig. 2.)

Example 3.—To construct a scale of 1/20,000 to show 100 metres.

On this scale, since 100,000 centimetres=1 kilometre, the length representing a kilometre will be 100,000/20,000=5 cms., that is about 2 inches. Consequently 3 kms. can be shown on about 6 inches of scale. In the absence of a scale of centimetres, we may proceed thus—

1 metre=39.370 inches; therefore 3 kms.=118,110 inches, represented by 118,110/20,000=35-91 inches. Divide this length into 3 parts and each third into 2 parts, each representing 500 metres. Sub-divide the left primary into 5 secondaries, each of nearly 1/5th inch, representing 100 metres. See Fig. 3 and compare it with the scale of metres, on the same R.F., on the Service Protractor.

2. As the value of a scale depends in a great measure upon the accuracy with which it is divided into equal parts, the following method may be adopted :—

To divide the line AB (Fig. 6) into, say, 9 equal parts. From A draw AC of indefinite length, making any convenient



angle (say 20° or 30°) with AB. Starting at A, set off along AC nine equal lengths so that the total length divided, AD, is approximately equal to AB. Join DB and then, through each point of division on AC, draw lines parallel to DB and cutting AB, which is then divided into 9 equal parts.

15. Special Forms of Scales

1. A map can only have one R.F., but it may have several scales in order to show different units of measure.

Example 1.-In military operations distances are sometimes measured by the time required to traverse them, and in this case the linear scale might be supplemented by a scale of hours and minutes.

To construct a scale of time for a column of troops marching at 3 miles an hour.

Suppose the map in use has a scale of 1/100,000, *i.e.* 0.6336inch to 1 mile or 1 inch to 1.578 miles; 6 inches will then be equivalent to about 91 miles, or something over 3 hours, which will thus be the range of the scale. Now 3 hours (=9 miles) is 5.70 inches. Lay off this length on the map, or on a small strip of good white cardboard or thick paper, and divide it into 3 parts marked and numbered :--hours 1, 0, 1, 2. Sub-divide the left division into 12 parts, indicating 5 minute intervals, and the quarter hours as in Fig. 4.

Example 2.—In military sketching it is sometimes convenient to make a scale of paces, since it is only a big man, or one who is consciously pacing long, who can pace a yard. A scale of yards should be given too, and both scales will naturally have the same R.F.

To construct, for sketching, a scale of paces RF $\frac{1}{15.840}$ (Assume that a pace is equal to 30 inches). RF $\frac{1}{15.840}$ is equivalent to 4 inches=1 mile=1,760 yards.

 $2,640 \times 36$ 6 inches=11 miles=2,640 yards=-30 paces =3,168 paces.

Therefore take 3,000 paces as the length of the scale

3,000 paces = 6 inches : From which x=5.68'' and the scale will be drawn and figured as shown in Fig. 5.

3.168 paces.

2. Diagonal Scale .- This is a device for dividing a primary division into very small secondaries. If carefully drawn, it is more precise than direct division with the best form of dividers. Smooth paper and a hard sharp pencil must be used. The scale is constructed as follows (Fig. 7) :—



Draw 10 equidistant lines, I, II, III... parallel to the scale line. In the figure the interval between these lines has been taken at about onesixth inch, but it may be any convenient distance. It is important that the lines should be exactly equidistant.

Draw a line at each end of the primary (in this case I inch division of a scale) perpendicular to these parallel lines. Divide the top and bottom lines (here inches) into the required number (here 10) equal parts and number the points of division (0 to 10) as shown. Join 0 on the bottom line to 1 on the top, I on the bottom to 2 on

the top; and so on as shown. Then to measure the distance 0.76 inch, say, run up the diagonal numbered 7 as far as the horizontal line VI. The distance from this crossing to the right-hand perpendicular zero line is 0.76 inch. (See also Plate XV.)

16. The Choice of Scale

Maps supplied to the army, in peace or war, vary in scale from a quarter of an inch to the mile, to three inches to the mile. The standard scale for training and for operations is one inch to the mile. Large scale maps $(2\frac{1}{2}$ to 3 inches to the mile) are issued for special types of training and will be issued, when possible, for pre-arranged operations in war. Small scale maps, quarter inch to the mile, are issued for specially mobile operations, and for transport and communications.

The scale at which a field sketch is made depends on the object in view, and therefore on the amount of information regarding the features of the country which is required. It is important that the student should realize that the area of paper in a map or sketch varies as the square of the number of inches to the mile (or of centimetres to the kilometre). Thus a portion of ground of a given area will cover *four* times as much paper on a scale of 2 inches to the mile as on a scale of 1 inch to the mile. Beware then of attempting to crowd upon a sketch at a scale of 1 inch to the mile all the detail and information which would appear more correctly at a scale of 2 inches to the mile.

Fig. 8 shows a square mile in its actual dimensions on different scales, and gives a good indication of the most suitable scale to choose for any given purpose.

Road or river reconnaissances and sketches of a defensive



FIG. 8.

or outpost position are usually made on scales ranging from 1 to 4 inches to 1 mile. Sketches which may be required for the defence of a village or town, or for the selection of a camp or billeting area, are generally made on scales ranging from 4 inches to 1 mile and upward.

CHAPTER IV

CONVENTIONAL SIGNS

17. The Object of Conventional Signs

1. Conventional signs are used where there is no room on paper to show the true outline, or to add a written description. For example a church is shown in its correct ground plan on a six-inch ordnance survey map, and alongside is given its name, but on a one-inch map the church is shown by a conventional sign and no name is given. The smaller the scale, the less room is there for plan and description and the greater becomes the number of objects which must be shown conventionally.

2. A map can show objects only in plan. Being itself flat it cannot indicate the height of objects. Heights are shown conventionally, either by writing a number of feet or metres against an object such as a bank or cutting, or by the methods described in the next chapter for showing ground features.

18. The Nature of Conventional Signs

For ease of recognition, conventional signs are as suggestive of the object represented as possible. Thus the sign for a windmill could scarcely be mistaken for anything else, and a cross or crescent is included in the respective symbols of churches or mosques. The conventional sign for any object is generally made to approximate to the appearance of that object as viewed from above, with the exception of trees, in which case the side view or elevation is always shown on Ordnance Survey maps. Signs should be as simple as possible to facilitate drawing and printing.

19. Ordnance Survey Signs and Signs on Royal Air Force Maps

1. As Ordnance Survey maps will constitute the basis of the training of the young soldier, it is important that the symbols employed on them should be carefully studied. They are shown on Plate II and the more important of these symbols will be found in the bottom left-hand corner of any one inch sheet.

2. Plate III shows the signs employed for the special use of air pilots. These are of importance to the Royal Air Force only.

TIONAL SIGNS AND WRITING FOR THE ORDNANCE SURVEY REVISED ONE-IN


HIN H MAP OF GREAT BRITAIN (POPULAR EDITION). PLATE II.



CONVENTIONAL SIGNS AND WRITING FOR



R HE ORDNANCE SURVEY REVISED ONE-INCH MAP OF GREAT BRITAIN (





PLATE III

SPECIAL ROYAL AIR FORCE CONVENTIONAL SIGNS

The Conventional Signs used upon the Quarter Inch R.A.F. Series.

Main Roads between Towns	
Other Metalled Roads	
Railways.	Station
Mineral Lines and Tramways	
Race Course	ARC
Church or Chapel with Tower or Spire	+
Golf Course	
Windmill	A
Lighthouse	····· \$-
Aerodrome	
 with Direction F.nding #/r Station 	🗄
Seaplane Station (Dotted over the land)	53
Landing Ground (permanent)	()
W/r Station with masts exceeding 250' in Height	😨
Air Navigation Light	····· Ø
Prominent Landmarks or Ground Signs	🖬 🛋
Prohibited Flying Area.	Summer
Name of Aerodrome, Landing Ground or	KENDON
Seaplane Station	HENDON
D.F. Station	+

Administrative Signs on Maps, Sketches or Annotated Photographs.

Aerodrome	
Temporary Landing Gro	und
Note :- The internal and the out on the groun only on large	symbol denotes character ine gives the actual shape id. This outline is given 'scale maps.
Army Co-operation	χχ
Bombing day or night	Squadron
Fighter	¥
Aircraft Park	
" Depôt	<u> </u>
Port Depôt	<u> </u>
Wing H.Q.	¥
Group H. Q.	
Airship	
Balloon	G.

CONVENTIONAL SIGNS IN COM

				-	
1	Usual Types	Variations	Notes		Usal
RAILWAYS	Normal Gauge	U.S.A. Belgium & italy	I. The number of railway lines is written against the conventional sign. 2. Indian maps have a variety of railway signs which should be studied in the list in the bottom margin of each map.	FERRIES	And a
RAILWAY			These symbols may be in red or black according to the colour in which the railway is printed.	FORDS	For
ROADS	Roads	France & Germany denoting road with avenue of trees. Belgium with Kilometre stones	1. Difference made between classes of roads depends on the country- look at the foot of the map. 2.As a rule road signs express the importance of a road but give no indication as to the surface.	MARSH LAND AND SWAMP	
ur i	Paths	(Red)India	3.0n Ordnance Survey maps roads are coloured to show whether surface is good or bad.)S RDS	4 0 0 0 0 0 0 0 Revi 0 0 0 0 . revi 0 0 0 0
BRIDGES	-Over bridge 	May be in black or red depending on the colour in which the road or railway is printed.	The type of bridge is shown by various symbols varying with each country: see at the foot of map. Some countries write against the bridge IRON; MASONRY; SUSPENSION, etc. to indicate its construction.	WOOL AND ORCHAF	a. Cau tan ta tan ta
CUTTING AND EMBANKMENT	Cutting	Sometimes in brown U.S.A.	Many maps do not show these features on small scales.	CHURCHES	Christian to the the Cross with or without Mohammer to the Crescent
/ERS	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	Non-perennial rivers are some- times shown by a broken blue line or in black instead of blue. Broken blue lines, however,	These symbols are practically universal. A stream is usually shown as a single line, then as	WINDMILLS WELLS	X ¥ Wi Y ⊙ W P Wild ○ ● Wes
RIV	~~~~~	may often denote that the course of the river is un- surveyed.	a thick, until its breadth reaches a stage where the banks can be shown as separate lines.	S	400
CANALS	Locks Usually shown thus Aqueduct Usually shown thus	Aqueduct (U.S.A.) Variations showing footpaths or towpaths, differ with countries see foot of map.		CONTOUR	Carr

usu Types	Variations	Notes
ler .	In England V or F is written along side the Ferry to show whether it carries Wheeled (Vehicular) or only Foot Traffic.	The type of Ferry, whether chain, oar or motor is often shown by the shape of the boat.
All and a second second	The Japanese carry the road across the river but show no bridge sign.	The road to the river is generally carried across dotted, or stops on the bank and the word FORD written.
	The two symbols are some- times mixed together. On Japanese maps the marsh sign is often partly black & partly blue.	In the case of Mangrove Swomps Jungle Swamp, etc: the swamp symbol is usually interspersed with a Tree symbol denoting type of swamp.
Trchards Tr lines & r spacing Woods to ed green black or green rar spacing	Latin-European Countries show trees in plan. Ex: 1:40,000 Belgium. 3. Deciduous 6. Coniferous Coconut Palm Trees Malay Gold Coast	 Many maps show different types of vegetation by various tree symbols in black or green. All maps differentiate between plantations and woodland by showing the former in a regular pattern, the latter in an irregular pattern.
wer or spire	France o o Interior dot implies trig. point Eastern Maps Special signs used for temples or pagodas	The idea of all these symbols is to suggest the religion by its correct emblem used as a conver- tional sign.
Wim r Water Mills	% France	
The second	I Contours may be numbered on the face of the map or on the edges. 2.The contours may be in black or red or brown, the latter being the most common. 3.Look at the margins of the maps to see if the VI. is in feet or metres.	Dotted lines may represent form lines (approx. contours) or may be inserted between contours spaced at the regular V.I. to show some underfeature of importance which would be missed by the ordinary contours.



PLATE V. THAL SINS FOR FLELD SKETCHING BSTACLES, DEPOTS, ORGANISATION etc. SEE PLATES III and VI an hering to be used. Words which should appear on the sketch are shewn in black. Form lines and spot heights the he ditch or raffic at all Bridges: State nature: Stone, Iron, Suspension, Ferry Elvingage Suspension whether it is dry or flowing and whether subject 120 w. 16d AVON Width of waterway in A 25 w. 80 Height of banks - - -6. State nature of foreshore and at what state of the tide it is practicable for landing. Quarries and all fild Mixed "elo precipitous ground are shown in the same manner as cliffs. e" of "Open." 180 "Variation unknown" ficient time to draw the crossbars, a railway may be ck or red line with the word "Railway' written along it. vay must be inserted as "broad, standard, narrow, or CALE FOR A SKETCH OF inches to I mile 4 2000 Yards 1000 1500 Ordnance Survey 1928.

MILITARY CO	ONVENTIONAL SIGNS	TO BE USED ON MAPS.
SU	CH ADDITIONAL SIGNS	AS OPERATIONS OF A PARTICLE WILL BE PUBLISHED INCO
Batteries and Gun Emplaced General	Nature of Arty.:-	Obstacles :- Abatis Win Entrodoment on posts
When scale allows individual Emplacements, fixed by photograph, are to be shown.	6"How., 18 Pdr., 12"etc.	Chevaux de Frise
Anti-aircraft Guns	۲	System of Trenches :-
Anti-tank - Ar Machine - Trench Mortars	tillery (* ^{Cavalry} or (* Infantry (* *	Old or disused trenches are shown dotted.
Dumps :-		Tenks
Supply	S	Tank Trap
Petrol	P	Road Block
Engineer	A	Mine
Hutmanta	Ľ	Mine - field
Dug-outs		or Boulders of 18 inches
Searchlight	*	Bridges :-
Observation Post	0	
Signal Office (Telephone or Teles	(raoh) 0 -	and Culverts in tons
Wireless Telegraph Station	Φ.w/z	Catastranta a di Città
Radio Telephony Station	0 w/1.	Emoankments and Cuttings :-
Beam Station	Φ.,	Height of Embankment in feet
Direction Finding Station	0 °	Depth of Cutting
Visual Signalling Station	00/1.	Water :-
Hospital, Clearing Station or Al	id Post	Width of Water-way in feet
Gas:-		Depth
Gas Projectors	ſt.	Woods :-
Gassed Areas (shade YELLOW when possibl	(e) (Us. (Mustard)	Average diamater of trees in thes spacing et
	SIGNS WILL BE SHOWI	N IN RED FOR BRITISH (AD AL

PLATE VI





20. Other Conventional Mapping Signs

Later on the soldier will have to use other maps, either at a station abroad or in war. The conventional signs used will not be the same as those of the Ordnance Survey. Differences will be found unimportant, however, if it is remembered that anything new will almost certainly be explained in the left-hand bottom corner. Plate IV is inserted in order to show the signs generally in use for the more important objects on maps other than those of the Ordnance Survey.

21. Conventional Signs for Sketching

The signs shown on Plates II, III (partly) and IV are suitable for use on printed maps. In sketching, however, signs must be bolder for convenience in drawing by hand, and others must be added to show the extra information that the larger scale of a sketch generally entails. These signs must also be known, and are given on Plate V.

22. Conventional Signs for Items of Military Importance

The maps normally produced in times of peace, and used for training, have no special military information printed on them. In war, however, and occasionally for reports or special exercises in peace, special military information is overprinted on the map. Conventional signs are as necessary for this purpose as for showing ordinary map detail. The proper signs to use are given on Plate VI.

23. Conventional Signs for Troops and Units

A sketch made to illustrate a military report must often show the dispositions recommended for attack or defence. The proper signs to use for this purpose are also given on Plate VI.

24. General on Signs

All the conventional sign plates which must be studied have been collected and arranged together, because it is sometimes difficult to be sure exactly which category is correct in any particular case. It should be remembered that the only sign list important in early study is Plate II. When the time comes to make the first military sketch Plates V and VI will be wanted. Plate III is required by the Royal Air Force only, and Plate IV will normally be for reference only.

CHAPTER V

RELIEF AND ITS REPRESENTATION

25. Hill Features and Methods of Representing them

The chief difficulty felt by most students in map reading is that of understanding the methods used to represent hill features. There are several ways in which hill features and heights may be indicated on a flat surface, viz. :---

i. Contours (including form lines).

ii. Hachures.

iii. Hill Shading.

iv. Layer Tints.

v. Spot Heights.

Methods i and ii are distinct in themselves and are seldom combined on the same map. Method iii is rarely found except in conjunction with either i or ii. Method iv is invariably associated with contours i, and method v is used on practically every map, in connection with one or other method or combination of methods.

26. Description of Contours

These are best explained by the following simple practical illustrations :---

All students will be familiar with the ordinary wooden or plaster models sometimes used to represent, in relief, hills and other geographical features. Say we have such a model, the scale of which we know to be 1/12, *i.e.* 1 inch on the model representing 1 foot on the ground. Place the model in an empty tank or bath and pour in water until there is a depth of 1 inch in the bath. The watermark will cut the model all round, 1 inch vertically above its base. Draw this watermark on the model with a pencil. Now add water until there are 2 inches in the bath and draw in the second watermark. Continue to add water by inches in this way, and to draw in the successive watermarks, until the model is completely covered with water.

On removing the model it will be found to be marked with a succession of lines which are vertically 1 inch above the other (Fig. 9). These lines are "Contours."

Now if a drawing of the model is made, as seen from above. *i.e.* a plan of the model on the actual scale, "Contours" at 1 inch vertical distance will appear on it, or in other words a map of the actual ground on a scale of 1/12 with contours at a vertical distance of one foot will have been made. The



Model of Hill with Contours visibly marked, and Plan of same.

vertical distance between the contours is known as the "Vertical Interval" (commonly written V.I.). Thus a footnote on a map "Contours at 1 foot V.I." means that any two successive contours are separated by a vertical interval of one foot.

27. Reading Contours

1. The relative position and curvature of contours affords clear evidence of the shape of the ground. The main conclusions which may be drawn from their shape and spacing are here considered. A comparison of the ground with a well contoured map will suggest others. The student must study this subject with care, as he who cannot understand the evidence of contours will understand neither the map nor the country it represents.

1 Strill

2. Supposing that a map were to consist of little else than unnumbered contours, and that no spot heights were added, it would be difficult or impossible to decide which was hill and which was valley. In such a case it would be possible to form two mental pictures of the ground, one correct and



FIG. 10.

one inverted. In Fig. 10 A–B might be valleys separated by the spur C–D, but it might also be a picture of a valley D–C between two spurs B–A.

3. Maps and sketches meet this difficulty by writing the height alongside, or in the actual line of the contour (Fig. 11). There is no room, however, to mark each contour, and attention may be necessary in order to find the approximate heights and to infer from them the direction of the slope. It will be noticed that where the bend of a lower contour points towards a higher contour, a valley (stream, re-entrant) is indicated, and that where the bend of a higher contour points towards a lower contour we are dealing with a spur (underfeature). Spot heights, given usually on the tops of hills or in valleys, help to show the direction of slope.

4. An expert map reader will seldom consult contour



FIG. 11.

numbers or spot heights for the general purpose of distinguishing hill from valley, because there is generally clear evidence of the slope of the ground in streams, lakes and ponds. A stream must be in a valley and a lake or pond in a depression. It is this simple fact that makes a study of the drainage the first step in the examination of any map.

5. Fig. 12 shows various slopes which are defined as *uniform* (both gentle and steep), like AB and CD, *convex*, like EF, or *concave*, like GH. If contours be drawn in plan to represent these various slopes, it will be apparent that their

in the state



FIG. 12.

spacing will, in each case, be distinctive of the particular kind of slope represented, as follows :---

- When the contours are evenly spaced as in plans (1) and (2), the slope represented is uniform. (The slope of river and stream beds is generally uniform except near the source.)
- When the spacing, reading from high to low, decreases, as in plan (3), the slope is convex. (The top slopes of hills are often, though not always, convex.)
- iii. When the spacing, reading from high to low, *increases*, as in plan (4), the slope is concave. (The bottom slopes of hills are generally concave.)

6. It may be noticed that uniform and concave slopes (1), (2) and (4) viewed by an observer at A, C or G, are visible throughout; in other words, there are no concealed portions to form "dead ground." Convex slopes (3), on the other hand, imply dead ground.

 Contours drawn close to each other indicate a steep slope; the further they are apart, the more nearly level is the ground. (Compare 1 and 2, Fig. 12.)

8. It is important to realize not only the capabilities, but also the limitations of contoured maps. A small scale map has no room in which to show the number or the accurate shape of contours characteristic of a larger scale. If the V.I. is 50 feet (as on one-inch maps), features of real tactical importance (but of a lesser height than 50 feet) may not be shown. On quarter-inch maps the V.I. is generally 200 feet, and comparatively large features are not shown.

28. Sections

1. Section drawing is seldom necessary in practice. It is explained because under certain circumstances it may be a useful method of finding the extent of dead ground, or of ascertaining whether one point is visible from another point (Sec. 36).

2. A section has been defined as "the *outline* of the intersection of the ground by a vertical plane." A good illustration is a cottage loaf of bread cut in half from top to bottom, for the outline seen when one-half of the loaf is removed is a full-sized section of the loaf. A knowledge of contours, and of the V.I., enables us to draw a section of a hill which will present a fairly accurate picture of the slopes as they would appear if a cutting were made right through that hill. It is drawn as follows :--- 3. On the map draw any straight line, AD (Fig. 13), running through the portion of the hill of which a section is required. Mark on this line the points at which it is intersected by the contours; then, either on the map, or on a separate sheet of paper, draw a horizontal line of equal length, AD, representing the level of the lowest contour, and mark accurately thereon the contour intersections. At each of these points erect a perpendicular line and mark on the right and left uprights equidistant points representing the V.I. to which the map is drawn. The vertical scale



FIG 13.

should be exaggerated to about six times the horizontal scale, otherwise the differences in height may not be appreciable. Through the equidistant points draw lines parallel to the lowest line, and mark these lines successively, corresponding to the heights of the contours which they represent. From X draw a line ascending through the intersection of the vertical lines with the contour lines until the hill-top is reached, and descending similarly to Y.

4. From this sketch (Fig. 13) it can again be clearly seen that where the slope is gentle the contours are far apart, and where steep they are close together. (See also Plate VII and Fig. 14.)

29. Form Lines

Form lines are approximate contours and are used when it has not been possible to survey accurate contours in the field. They show the ground in the same manner, but are not necessarily at regular intervals, and are not reliable for exact information.

30. Hachures

These are lines drawn down the directions of steepest slope. For gentle slopes they are fine and far apart and as the slope becomes steeper they are drawn more heavily and more closely together. They give a good idea of the shape of the ground but are artistic rather than accurate, and afford little positive information. Hachuring is seldom uniform over different sheets of a map. A slope which would be insignificant on a sheet representing a hilly country might be a remarkable feature in a flat country. In the former case it might possibly not be indicated by hachures at all; whilst in the latter case it must be given some prominence. It is evident that hachures can indicate the existence of a slope, but cannot give its degree with any approach to accuracy. Hachures are seldom used nowadays and will not be found on any recent British maps.

31. Hill Shading

Hill shading aims at showing, by depth of tint, what hachures show in line work. The shading may be applied to all slopes according to their degree of steepness, or it may assume a light which is supposed to cast a shadow. In the latter case the light is generally assumed to be oblique (from the North East corner).

32. Layer Tints

When the ground between contours is coloured by tints which vary according to the level, the map is said to be layered. When differences of level are considerable, a layered map is read more easily than any other, since the relief stands out as on a model (Fig. 9). It is the most generally useful method of showing relief, but fails to show minor features or variations of shape, and tends to convey the impression that the ground between contours is level.

33. Spot Heights

In addition to any other method, a good map always gives the height of a number of isolated points. On hachured or shaded maps these give the only exact information as to level which the maps contain. Spot heights are particularly valuable for showing minor relief between contours.



FIG. 14.

34. Slopes and Gradients

1. The slope (rise or fall) of the ground between any two points may be expressed as an angle—e.g. 5 degrees—or as a gradient— $e.g. \frac{1}{15}$. Those who use clinometers, or sights which measure angles, naturally define a slope as being so many degrees of elevation or depression from a horizontal plane. The slopes of roads and railways are usually expressed as gradients, or as a rise or fall of so many units in a given distance.

2. In the bottom diagram of Fig. 14, AB is the distance in plan between successive contours, whilst CB is the Vertical Interval, to which reference has been made previously. AB is called the *Horizontal Equivalent* (usually written H.E.), and on examination of Fig. 14 it will be seen that as the slope increases the *Horizontal Equivalent* diminishes. Thus whilst the V.I. remains the same in all three diagrams, AF is half AD and AD is half AB.

3. The gradient is the tangent of the angle of slope $\binom{V,L}{H,E,}$ and the relationship between slope V.I. and H.E. may be founded on the fact that the tangent of 1 degree is approximately $\frac{1}{40}$ * [or, when the slope is 1 degree the ground rises (or falls) one foot in a distance of sixty feet].

Thus, if the angle of slope is t degrees,

then
$$\frac{V.I.}{H.E.} = \frac{t^{\circ}}{60}$$

or $V.I. = \frac{t^{\circ} \times H.E.}{60}$
or $H.E. = \frac{V.I. \times 60}{t^{\circ}}$
or $t^{\circ} = \frac{V.I. \times 60}{H.E.}$

One word of caution must be added. The V.I. is usually expressed in feet and the H.E. is generally measured in yards, but the rules given above are only true when both are measured in the same unit.

35. Examples of working in Slopes and Gradients

A certain M.T. Column, fully loaded, cannot climb gradients steeper than 1/5, and it is required to find from the map a practicable road from A to B.

A convenient road goes up a hill on which the contours

^{*} $_{57:3}$ is more accurate and should be used when the slope is over 10 degrees.

(V.I. of 50 feet) are, at the minimum, 100 yards (or 300 feet) apart. What is the gradient ?

The gradient
$$= \frac{V.I.}{H.E.}$$
$$= \frac{50}{300}$$
$$= \frac{1}{6}$$

and the road is therefore passable.

The problem might, however, be solved by answering the question: What is the distance in plan between contours at a gradient of 1/5?

but
$$\frac{V.I.}{H.E.} = \frac{50}{H.E.}$$
 and by definition $= \frac{1}{5}$
 $\therefore H.E. = 250$ feet
 $= 84$ yards

and, as the contours are actually further apart than this, the road is passable.

36. Visibility

1. It is often of importance to discover from the map whether two points are mutually visible. On perfectly open ground, *i.e.* without trees, hedges, buildings or other obstruction, one point will be visible from another so long as the ground does not rise above the line joining them. Thus, if the country between two points is level, evenly sloping, concave, or lower than both of them (*e.g.* a valley), they will be intervisible. On the other hand, where a hill or a convex slope intervenes, one point will not be visible from the other (Plate VII and Fig. 13).

2. Visibility problems can often be answered by simple inspection of a contoured map or sketch, but occasionally there may be doubt. For example, a hill between the two points may be higher than one of them, but if it does not rise above the line joining them they will still be intervisible. It is not easy to decide this point by inspection, and a quick method of finding the right answer is required. Before describing that method a word of caution is necessary.

3. The extent to which visibility problems can be solved from the map depends upon the size of the V.I. If the V.I. is small, e.g. 10 feet, the unrepresented ground features are small, and visibility can be determined with some accuracy, and yet, even so, features higher than a man's eye may cause the facts to disagree with a perfectly correct sum. But if the V.I. is large, e.g. 50 or 25 feet, the unrepresented ground features are large also, and include all elevations and depressions of less than 50, or 25, feet, as the case may be. Visibility, therefore, should seldom be assumed from calculation only, without inspection of the ground, unless common sense shows that there can be no obstacle, as, for example, in the case of two neighbouring hill summits.

4. Standard and small scale maps have V.Is. varying from 50 to 250 feet. It is evident that, in flattish and wooded country, visibility problems on such maps are likely to have little more than a theoretical value. They will, however, be of more value in showing up places to avoid, than in choosing places from which to see.

5. There are four methods of solving the visibility problem, and they all depend on ascertaining whether the line of sight between the two points in question clears or touches intervening features.

i. First Method .- By gradients.

To find whether two points A and B are intervisible, draw



a line joining them. Note any points on that line which are likely to obstruct the line of sight between A and B, and estimate their height. Suppose there be such a point D whose height is 260 feet, and suppose the height of A is 300 feet and that of B 200 feet. Scale off on the map the distance AD and also the distance AB; suppose AD = 1,200 yards, and AB = 2,700 yards.

Slope AD = a drop of 40 feet in 1,200 yards $=\frac{40}{1,200\times3}=\frac{1}{90}$ Slope AB = a drop of 100 feet in 2,700 yards $=\frac{100}{2,700\times3}=\frac{1}{81}$

This calculation shows that the slope AB is steeper than the slope AD, and, therefore, D will obstruct the view. Fig. 15 shows this solution graphically. Had D been below the line of sight AB, there might yet have been other doubtful points each of which would have had to be tested in turn. In such a case it is quicker to use another method.

ii. Second Method.—By a simple proportion sum. On Plate VII E is the top of a hill which may, or may not, be visible from the hill A. The hill D is the intervening feature-

Distance A to D 700 yards.

Distance A to E 1,520 yards.

Difference in height A and D 50 feet.

Difference in height A and E 75 feet.

The line of sight from A to E rises 75 feet in 1,520 yards. The amount it will rise in 700 yards is found by proportion as follows :--

700:1,520::
$$x$$
: 75
or $x = \frac{700 \times 75}{1,520}$
 $= 34.5$ feet

It therefore passes about 15 feet below the summit of D and E will not be visible from A.

iii. Third Method.-By drawing a section (Plate VII). This method requires time, but has the advantage that dead ground (ground invisible to the observer) is clearly shown.

iv. Fourth Method .- By proportion (Plate VII).

Join the line AB. The terminal heights are 303 and 403, and the difference is 100 feet (or four times the V.I.). Divide the line AB into parts representing the H.Es. between A (303) and 325, 325 and 350, 350 and 375, 375 and 400, and between 400 and B (403).

For example (measurements were made in this instance with a centimetre scale, but any convenient unit may be used).

AB is 9.7 cms.

Now the 1st H.E. (measured from A) is $\frac{22}{100}$ of 9.7 or 2.13 cms.

The	2nd,	3rd	and	4th	H.Es.	are	each	100	of 9.7 or	
-----	------	-----	-----	-----	-------	-----	------	-----	-----------	--

2.43 cms., and the three measure ... 7.29 ,, 2.43 cms., and the three measure ... The last H.E. is $\frac{3}{100}$ of 9.7 $\frac{0.29}{2.71}$ Total ... 9.71

Set off these measurements, and the points marked indicate where the line of sight is at a height of 325, 350, 375 and 400feet. Compare these heights with the actual contours of the map and see whether at any point the ground is higher than the line of sight. In this actual example it is obvious, on inspection, that the ground near D is higher than the line of sight, and that A and B are not intervisible. This method is convenient and quick. The division can be made on a separate piece of paper, which is then laid on the map.

NOTE .- A very practical application of this method is as follows :-Take a piece of elastic ribbon. Mark on it divisions of equal size,



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say $\frac{1}{2}$ inch, from end to end. To solve a visibility problem it is only necessary to stretch the elastic so that two divisions fall on A and B (the points whose intervisibility is required) with the necessary number of divisions between them equal to the number of contour intervals between A and B. By inspection the intervisibility can be ascertained. In the example given above the line A and B has to be divided into 4 parts. Place one division over A and stretch the elastic till the fifth division to the right is over B. Keeping the same tension shift the elastic to the left till A falls 3/25ths to the right of the 1st division. The divisions between A and B now mark the points at which the height of the line of sight AB is 325, 350, 375 and 400 feet. By inspection ascertain the intervisibility.

 From the foregoing considerations, the following rules can be formulated:—

- If the map or sketch shows two points on the opposite sides of a valley standing well above any of the intervening ground, these will be intervisible.
- ii. If, between any two points, a feature is represented higher than both, the points will not be intervisible.
- iii. If, between any two points, a feature is represented higher than one of the points, the points may, or may not, be intervisible.
- iv. When a slope is shown by the map to be convex, two points thereon will not be intervisible.
- v. When a slope is shown by the map to be concave, two points thereon will probably be intervisible.
- vi. When ground is shown by the map to be level, the intervisibility of two points will depend entirely upon the absence or presence of such objects as houses or trees.

37. Visibility Diagrams

Visibility diagrams indicate which portions of the ground are visible, and which are invisible to an observer at some definite observation post. They are also a practical aid to identifying objects from an observation post when a good map is available.

The principles given above may be used to determine on the map the areas visible from the observation post, but personal reconnaissance is necessary also, as trees, hedges, and other objects not shown on the map, may considerably affect the view.

To construct a visibility diagram, identify the observation post and the reference object on the map, draw a line joining these two, and mark it 0° . Set off lines at 10° interval, radiating from the zero line on either side of it. Study the features, mark on the map the objects and features which interfere with the view and then draw in those areas which are invisible from the observer's position (Fig. 16).

From the completed diagram so constructed copies may be traced at will. Such copies need show no more than grid, invisible areas and zero line, which will suffice as a guide for use with any map at the same scale (Fig. 17).





that if the grid lines everywhere point to true north, the grid cannot be rectangular. It is usual to make one grid line coincide with a meridian. On this "standard" meridian the grid points to the true north. All other vertical grid lines are drawn parallel to it, and do not point to the true north, but in each case to a different and imaginary point called the grid porth

From Fig. 20 it will be seen that grid north is east of true north when east of the standard meridian, and west of true north when west of that meridian.

The angle between grid north and true north is known as "the angle of convergence," and it is evident that this angle



increases the further the grid departs from the standard meridian.

iii. Magnetic North.—Magnetic north is the direction in which the compass needle points (unaffected by any local attraction): *i.e.* the direction of the magnetic pole at any point. The magnetic north pole changes from year to year and thus the magnetic north, varies from year to year as well as from place to place.

Plate VIII shows the value of the magnetic variation all over the world in 1927. At present (1927) the variation of the compass in Great Britain and Ireland varies between 13° west in the east of England and 19° west in the west of Ireland, and it is diminishing by about 11 minutes annually.

It should be noted here that (a) every ordinary compass has its own individual variation which will differ by a constant amount from the local magnetic variation, and (b) compasses





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30° ****** 150°

Lines of WEST Variation

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are affected by local attraction, such as a hill in which magnetic iron ore is to be found, guns, tanks, etc. Thus, before using a compass for accurate work, certain precautions must be taken (Chapter X, para. **68**).

To test the individual variation of the compass proceed as follows :---

1. Identify on the Map and Ground, the standpoint "A" and some distant object "B."

2. From map with protractor find Grid (or True) bearing of "B."

3. With compass, find compass bearing of "B."

4. From the Grid (or True) and Compass Bearings, find the compass variation.

5. Compare the compass variation with local magnetic variation.

(a) If they coincide, the compass is correct.

(b) If different, the compass will have an individual variation of so many degrees East or West of Grid (or True) Magnetic North.

41. Conversion of Bearings

1. As stated in Section 40, the bearing of any object on a

map may be expressed in one of three ways, *i.e.* with reference to the true north, grid north or magnetic north. On a gridded map all bearings must be given with reference to grid north, and not to true or magnetic north.

2. Gridded maps show in the margin the angle between grid north and magnetic north (Fig. 21), with an additional note stating the angle between the grid north and the true north for that sheet. This enables the user of a map to convert a bearing given with reference to magnetic, or true north to grid north.

3. Supposing the variation of a compass in a particular locality to be 20 degrees West, a magnetic bearing of 20 degrees will give true North. Similarly, if the variation is 20 degrees East, a magnetic bearing of 340 degrees (360 minus 20) will give true North. It will therefore be seen that when the



Annual decrease about 12'. Grid North in the centre of this sheet is 0° 28' 54" West of True North.

variation is West it must be deducted from, and when the



variation is East it must be added to, the magnetic bearing in order to give the true bearing. It will also be seen that when grid North is West of true North the difference must be added to, and when the grid North is East of true North the difference must be subtracted from, the true bearing to give the grid bearing (Fig. 22).

If these rules are followed, conversion presents no difficulty, but it is essential to draw a rough diagram to prevent errors of sign being introduced.

Example 1 (Fig. 23) :-



True bearing = 140 + 20 = 160. Grid bearing = 140 + 20 - 4 = 156





Example 2 (Fig. 24) :--

Magnetic north is 13° 30' West of Grid G.N. M.N North. TN Grid North is 1° 30' West of true North. Magnetic bearing of A from P is 5°. Com-What is the true bearing and the grid bearing? Magnetic variation $=13\frac{1}{2}+1\frac{1}{2}^{\circ}=15^{\circ}$ W. $=365^{\circ}-15^{\circ}=350^{\circ}.$ True bearing Grid bearing $=350^{\circ} + 1^{\circ} 30' = 351^{\circ}$ 30' Or from diagram direct : $=365^{\circ}-13\frac{1}{2}=351^{\circ}30'$. FIG. 24. Grid bearing

Example 3 (Fig. 25) :--



Magnetic north is 13° West of Grid North. Grid bearing is 340°. What is magnetic bearing ?

Magnetic bearing $=340^{\circ}+13^{\circ}=353^{\circ}$.

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CHAPTER VII

SYSTEMS OF REFERENCE

THE GRID, AND HOW TO GIVE AND READ REFERENCES

42. The Principle of a Reference

The purpose of this chapter is to enable the student to understand the methods of reference used in describing the

position of a point on the various maps he may be called upon to use.

A few preliminary remarks are necessary.

If we look at Fig. 26 which represents two lines XOX' and YOY', drawn at right angles and crossing one another at O, and presuppose that the position of

point O is known, the position of point P can be described by the lengths of ON and NP (where NP is perpendicular to XOX', or parallel to YOY').

The basic principle of the systems of reference under discussion is that outlined above. In all systems XOX' and YOY' are, respectively, east-west and north-south lines, and ON and NP are termed eastings and northings.









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43. Systems in Use

There are in use two systems, similar in principle but differing in detail. These are :---

i. The British System adopted in 1919 and to continue in use on maps of Great Britain until a new Ordnance Survey edition appears. Suitable for large and medium scales, this system cannot be used on small scales, and is of little assistance in describing the movements of mechanized troops or in framing orders concerning a large area! This system is being superseded by :---

ii. The Modified British System, which is already is use on maps used for training overseas.

There are two rules which apply to both systems-

- (a) Easting comes first, Northing second.
- (b) The same number of figures must be given in both cases and the reference must always be an even number of figures. (It may, or may not, begin with a letter.)

44. The British System

1. On the standard (or one inch) scale-Plate IX-it will be seen that the map is divided up into squares by lines running north and south, east and west. Every tenth line is thickened, and if a square bounded by thick lines is measured, its sides will be found to be 10 kilometres long. Each of these squares is given a letter (e.g. P, L, M, U, Q and R) and all are identical in size. The south-west corner of each lettered square corresponds to the point O of Fig. 26. From this point references are given, the thin lines merely serving to divide each of the thick lines into tenths (or kilometres). Referring again to Fig. 26 the first step is to measure the easting (or ON). Count the thin lines from O (the west thick line), the first thin line being 1, the second 2, etc., until the thin line immediately west of P is reached, then completing the easting by dividing the final kilometre into tenths by eye. Follow the same procedure to find the northing (NP).

Refer now to Plate IX and find Sandy Lodge Station in square Q. It will be seen to lie east of the 3rd thin line, and to be one-tenth of a kilometre beyond. The easting is then 31. Similarly it lies north of the 2nd thin line and is 7 tenths of a kilometre beyond. The northing is 27 and the complete reference Q.3127.

Verify the following additional references :---

Hatch End Station Q.7506. Chipperfield Church P.8812. Bunkers Farm L.3351.

2. An extract from a large scale map (1/20,000) is given on

Plate X. This is the scale for which this particular system was designed. The squares represent the same areas on the ground as those on the one-inch sheet, and are lettered in the four corners, but as 1/20,000 is about three inches to the mile, the sides of these squares are about three times as long as on the one inch. Thick lines, as before, bound the 10 kilometre squares, and thin lines divide them up. References are easier than on the one inch, because in each little (kilometre) square are printed two figures, the first of which is the number . (eastwards) of the west edge, whilst the second is the number (northwards) of the south edge. Refer to Plate X (which shows only a portion of a big square) and consider " old chalk pit " which lies in little square 21. It will be seen to be onetenth of a kilometre eastwards in this little square and the easting is therefore 21. Similarly, it lies 7 tenths north and the northing is 17. The full reference is then 0.2117.

Verify the following additional references :

Rose Cottage	Q.1120.
Dandridge Copse, North corner	Q.2605.
Woodmancott Church	Q.0124.

45. The Modified British System

1. In the former (British) system the square in which references were given has a 10 kilometre side (=10,000 metres, or if the grid is in yards, 10,000 yards). On a quarter inch map this square has a side of less than an inch and a half. The size of square in the modified system has been enlarged 10 times to prevent such confusion, and this enlargement is the only important difference between the two systems.

2. Consider Plate XI-an extract from a 1/250,000 (or nearly quarter inch) map of the country near Hong Kong. First note the thick lines. These are edge lines of the square in which references are given. Plate XI represents the lefthand bottom corner of the map. Look at the "incidence of letters on the grid " diagram on the right of the plate, which shows that the correct letter to use is P. A diagram like this is printed on every map. Now look at Funglokchau (marked with ring and arrow) and note that the reference is P.0981. exactly as it would have been in the British system. Look now at the explanation of " how to give a reference on this sheet." A similar explanation is given on every map. Note the way in which marginal figures are shown, and note also the purple 0 overprinted on lines marked 0 in the margin. Figures like this are overprinted at more or less regular intervals on every 0 line and every 5 line (Plates XI and XII).

3. Now consider Plate XII-an extract from a map of







Points are described by their Coordinates in kilometres, in the large lettered squares. The easterly Coordinate is always given first.



Thus the point P, in the small square 21, is described as :-

M 2317 (tonearest100 metres) M 232174 " 10 ")



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Unit. metre Square. 10000 Reference to nearest. 1000 Nearest similar reference distant 300 miles MODIFIED BRITISH SYSTEM (Large Scale)

1:25,000

Taken from the 1:25,000 JOHORE SHEET 312d



PLATE XII.



nee Survey, 1929

DIAGRAM SHOWING HOW GRID NUMBERS ARE SHEWN ON THE FACE OF THE MAP.





Singapore Island at the scale of 1/25,000. The scale is ten times as large as that of Plate XI.

Measure the distances on paper between grid lines on these two maps and note that they are nearly, but not quite, the same. They differ because the Singapore grid is in yards and the Canton grid in metres. Had both grids been in yards the distances on paper would have been the same. The distance measured on the Singapore grid represents 1,000 yards; that measured on the Canton sheet represents 10,000 metres. In other words, the square used on small scale maps is subdivided on large or standard scale maps by a printed decimal division, and as the small scale grid lines represent tenths, the large scale grid lines represent hundredths. On the small scale the numbers are from 1 to 9 and on the large scale from 01 to 99.

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The references on the large (and standard) scale are given in six figures, three for easting and three for northing. Refer again to Plate XII.

Look at point Paya Lebar II and follow, with the explanation on the right of the plate, why its reference is 903161. Note the style of showing marginal numbers, and note the purple figures printed here and there along lines.

The student will have noted the absence of letter. Each lettered square (area of reference) has a 60 mile side (100,000 yards or metres) and is, then, so large as to include several large scale sheets. When working with large or medium scale maps it is no longer necessary to quote the letter, but there are 6 figures in each reference.

46. On References generally

During training and at exercises or manœuvres at home stations, it is common to rely in orders or reports upon familiar names of towns, villages, cross-roads, etc., and to omit references. In war, or in training overseas, the danger of this practice is at once apparent.

Unfamilar names and the mistakes which may have been made in spelling or transliterating them are likely to introduce doubt and confusion.

When the name of a town, village, wood, stream, etc., is mentioned for the first time in an order or report a grid reference must be given.

The essential point is that references should be clear to the recipient. Within large squares (e.g. 1,000 metre squares at 3 inches to the mile) full of names and close mapping detail full references should be given. Within small squares (e.g. 1,000 metre squares on the one inch) and with bold names and clear mapping the reference may be simplified. As long as it is clear and unmistakable the reference may be given by the co-ordinates of the S.W. corner of the square e.g. 3207, or Q.70, etc., according to scale.

It is often necessary to refer to areas for tactical purposes. The area of a square may be indicated by the co-ordinates of the S.W. corner—e.g. Bivonac area squares Q.70 and Q.71—or squares 7363-7463 (according to scale).

47. On Cross Referencing between Large and Small Scale Maps (modified British)

Consider Fig. 27. A commands a force operating in the area of the quarter inch sheet outlined. B commands a unit working on a standard (1/50,000) map covering the hatched





area. A's references in orders, etc., are of the type Q.3145. B will naturally follow those orders on the quarter inch, but for his own purposes will use a reference of the type 308451.

If B reports activity at 483608, A knowing his locality, will look for 0.4861 on the quarter inch.

48. Instruction on the Grid System

Emphasis in instruction should be put on lines rather than on squares. Squares are formed, of course, by the intersection at right angles of two sets of equally spaced parallel lines, but they are not essential to the system. The lines, on the other hand, are essential and act as a set of scales by which to measure the distances ON and NP of Fig. 26.

The tendency to think in squares leads to three undesirable results :---

i. The inclusion of numbers in small squares all over the map.

ii. The idea of a square of fixed size. On scales so different as the 1/20,000 (or 3 inch) and the 1/250,000 (or quarter inch) this is impossible.

iii. The inversion of references. Thus in a square in which 31 appears (often called square 31) the impulse is often to refer to a point as 3106 instead of 3016.



If romers are not issued, they can be made on a piece of paper or cardboard as follows: Take one corner of a sheet of paper or cardboard and number it nought. Set off along both edges the distance between grid lines. Subdivide this distance into tenths and number them from 0-10 outwards from the corner or zero point.

The divisions of a Romer allow of a more correct measurement than can be made by eye and if necessary can be further subdivided by estimation. Thus, in Fig. 28, it is seen that O is 41/100ths East and 59/100ths North of its appropriate East and North lines.* This is known as a "Pin Point" reference and is seldom required except by technical troops.

50. Foreign Systems

In order to describe foreign methods of referencing the following terms must be used :---

Unit of reference is the number represented by the estimated tenth of the side of the square. In the British Modified System this is 100 yards or metres on the one inch, and a thousand yards or metres on the quarter inch (see the explanatory diagrams at the side of Plates XI and XII).

Area of Reference is the area or square, within which references are being given.

51. Use of Foreign Systems

1. Foreign grid systems can be used in the style of the Modi-

MAP REFERENCING when Grid Lines are spaced at fives instead of tens note construction of "Romer"

(example of this spacing-the German 1:100,000.)



Full reference 93414859.



PLATE XIII.



fied British System. The unit of reference is generally 100 metres on large and standard, and 1,000 metres on small scales. The only difficulty arises on certain maps, about the scale of 1/100,000, where the distance between grid lines is 5,000 instead of the ordinary 100 or 10,000. Fig. 29 illustrates the way in which references can be given on such maps with the aid of a "Romer." In cases such as that illustrated by Fig. 29 the unit of reference is still 100 yards, but the division by eye into fiftieths is impossible-with a Romer it is easy if care be taken. The Romer scales are divided into main divisions of 0 to 5 nearest the margin and from 5 to 10 farthest from the margin. If the distance from east and north is already more than an odd 5 (i.e. more than 15, 25, 35, etc.) the scale farthest from the margin is used. If the distance from east and north is more than an even 10 or less than an odd 5, use that nearest to the margin.

2. Plate XIII shows how marginal figures are given on some foreign gridded maps of to-day. Note that on the German, as on some other systems, the figures for reference are printed larger than the additional (and for reference unnecessary) survey figures. The same procedure is followed in the Modified British System.

CHAPTER VIII

SETTING THE MAP AND FINDING POSITION ON IT

52. Setting a Map

A map is said to be set or "oriented" when it is laid out in direct correspondence with the ground, so that the true north on the map corresponds to the North Point. If, after setting, the directions between features on the ground are then compared with the same directions as shown on the map, they will be seen to be parallel. A map may be set by compass or by objects recognizable both on the ground and on the map.

53. Setting by Compass

1. Lay the compass, opened, over the "magnetic north" line (produced if necessary) given on the map, so that the notches representing the zero line of the compass fall directly over the magnetic north line of the map. Now revolve map and compass together until the needle pointing to magnetic north is on the same line. The map is now set. 2. If true north only is shown on the map (either by a special marginal north point or by the east and west margins of the map itself), then set off magnetic north from true north with the protractor, draw in the magnetic north line and proceed as above.

Strictly speaking, it is not absolutely necessary to draw in the magnetic north line. If the compass is aligned on the "true north" line, and map and compass are revolved until the compass card (inner graduation) reads the amount of the local variation east or west (against the index at the hinge), the correct setting of the map will have been obtained.

3. British military maps are normally over-printed with a grid, and in the margin of the map information is given as to the relation between grid north, true north, and magnetic north, for that particular sheet. Thus, either of the above methods can be used, substituting grid north for true north and the angle between grid and magnetic north for magnetic variation.

54. Setting by Objects

A map can be set on the ground without using the north point as follows :---

i. If the observer's position can be identified as some point marked or known on the map, the next step is to identify, also on the map, some distant object which can be seen on the ground. Join the two points by a straight line. Then turn the map about until this line points to the distant object. The map is then set.

ii. Even if the exact position of the observer cannot be identified on the map, it may be possible, by moving slightly to one side or the other, to find a place in prolongation of some straight road, railway, canal, telegraph line or other feature shown on the map. Fig. 30 should be studied in reading this and the subsequent paragraph. It is not necessary that the straight line should be continuous. It may happen that a distant spire and a near-by fence corner are seen to be in a line from the observer's position and can be identified on the If then the map is so placed that the line through them coincides with, or is parallel to, the same line in nature, the map is "set." It sometimes happens that two conspicuous points appear opposite each other on either side of the observer (say at P). In this case draw on the map the line joining them, and lay the map on the ground so that this line points to one of them (say F). Now look in the opposite direction and see if the other point, say G, is in prolongation of the line. If it falls to the right (left) move to the right (left) and try again.

iii. A map can be set approximately for reading by identifying on the map prominent objects that can be seen. The map



FIG. 30.

is then held so that the directions between these objects as they appear on the ground and on the map are parallel to one another.

55. Finding Position on a Map

1. It will be observed that in the case considered under Sec. 54, ii, above, the position is not fixed, but only a straight line on which that position must lie. With this information, however, the map being set, it is usually quite easy to determine the position with all the accuracy required for map reading, as apart from sketching.

2. In general, in fully developed and fully mapped countries like the United Kingdom, the correct position can be fixed from map detail. The position is first fixed roughly in relation to the greater features around, such as hills, villages, woods, roads and the like. The locality being thus identified, exact location is found by means of the smaller features. For this purpose, the intersections of fences, the windings of streams, the presence of farmhouses, lanes and tracks, corners of copses and numerous other minor features are utilized according to circumstances. Here, as in setting, it is often easy to identify on the map two fences or other straight lines which.

if produced, intersect near the required spot. (Refer again to Fig. 30, in which DE is a straight length of railway line. Standing at A it is seen that by moving a few yards in a S.W. direction to B, the observer will be in line with DE and by moving towards D to the point C he will be on the line FG, which line, if produced to C, will give him his position.)

56. Resection

It may happen occasionally that the country is so open, or the mapped detail so meagre, that position cannot be found from detail near by. In this case it is necessary either to move to some spot which can be identified, or to employ one or other of the methods of resection by compass. For details of compass resection see Chapter XVI, Part III. Resection can, however, be done easily and quickly with a piece of tracing paper as follows :—

Pin a piece of tracing paper on a board and lay a ruler upon it. From any convenient point marked on the paper as a pivot, and without moving the board, draw a line along the straight edge of the ruler in the direction of each of three known distant points. Then remove the piece of tracing paper from the board and apply it to the map so that the three lines pass through the distant points, as marked on the map ; the pivot point is the required position and can be pricked through. If tracing paper is not available, ordinary paper may serve the purpose.

CHAPTER IX

COPYING AND ENLARGING A MAP

57. Copying a Map

Maps which are to be copied at the same scale—*i.e.* without reduction or enlargement—may be first traced on tracing paper, and then transferred to a fresh sheet of paper as follows:—

Place a piece of carbon paper between the tracing and a clean sheet of paper and fasten both down by drawing pins. Now follow the lines with a pointed instrument and thus "transfer" them to the fresh paper. In the field, an excellent substitute for carbon paper can be made by rubbing lead pencil dust on a piece of thin paper. Any sharp piece of wood will do for the tracing instrument. A map may also be transferred direct without a tracing; but there is some danger of damaging the original with the point. PLATE STAN



ENLARGING AND ADDING DETAIL



Scale I" to I mile.



Detail added from photographs in purple. reconneissance in red.

Tracing cloth is useful for copying; it is tough and will bear much handling. Draw on the glazed side and put washes of water colour, if required, on the back, making them darker than they are intended to appear on the front.

58. Value and Use of an Enlargement

Enlargement is often useful, but should be done with caution and a proper sense of its value and limitations.

Mere enlargement adds nothing to the information given on the map, which remains precisely the same as on the small scale original. The details on a small scale are of necessity generalized and in some cases exaggerated. Enlargement may, however, be advisable for one or other of the following purposes, viz. :---

i. To serve as a basis for a more detailed sketch at a larger scale.

ii. To provide room for writing notes and descriptions.

The scale of the original must be stated on every enlargement.

Plate XIV shows an enlargement, on a scale of 4 inches to a mile, from a 1 inch to the mile map, with additional information added from photographs and reconnaissance.

59. The Method of Enlarging a Map

The general idea of enlarging by eye is to copy the detail shown inside a small figure (square, triangle, etc.) on the map into a similar but larger figure on the fresh paper. In theory it does not matter what sort of a figure is chosen, but in practice the figure which is easiest to draw is naturally the best. Usually enlarging is done by "squares" because many maps are already squared, and require no further subdivision except by drawing in the diagonals, as in the so-called Union Jack method. If diagonals are drawn in, other lines may be added by joining up the points at which the diagonals intersect each other. By drawing all these lines the map will be divided into small triangles. However the map is divided, and in practice it will be wise to keep to the grid squares and their diagonals, the fresh paper must be divided up in the same way, and the detail sketched in at its enlarged scale by eye.

60. Examples

1. It is required to enlarge a gridded quarter inch map to one inch to the mile.

> The grid squares are 10,000 yards. The ratio is, obviously, as 1:4.

PLATE XIV

Thus the sides of the grid on the enlargement should be 40,000 yards, as measured on the quarter inch grid.

Prick through from the quarter inch map to the paper on which the enlargement is to be made, the corners of a 40,000 yard (quarter inch) grid, and draw lines through the holes.

Add diagonals to both original and enlargement copy detail by eye.

2. It is required to enlarge a portion of a map on a scale of 1/63,360 to a scale of 1/20,000. The original is not gridded. Draw on the original a system of squares with sides of one inch length. On the paper on which the enlargement is to be made, draw a similar figure whose sides are of the required ratio, viz.—

 $\frac{1}{63,360}$: $\frac{1}{20,000}$: 1 inch : X inches X=3·168 inches

Subdivide the figure as necessary and copy the detail by eye.

CHAPTER X

THE SERVICE PROTRACTOR AND THE PRISMATIC COMPASS

61. The Service Protractor

The rectangular service protractor, "A," Mark III, is illustrated on Plate XV, where the obverse and reverse are shown together. The protractor is of ivorine, and is 6 inches long by 2 inches wide. The following scales in British units are shown :—

On the front-

			Primaries.	Secondaries.
	1/20,000		1 mile.	
	1/20,000		100 vards.	20 vards.
	1/100,000		1 mile.	1 mile.
	1/100.000		1.000 yards.	100 yards
	1/250,000		1 mile.	4 mile.
	1/250,000		1.000 yards.	200 yards
	2 inches=1 mile	:	100 yards.	20 yards.
In	the back-			
	1 inch=1 mile	***	100 yards.	50 yards.
	$\pm 10cn = m1e$			

and a scale of inches, with diagonal scale for hundredths of an inch.



On the back in metric units-

		Primaries.	Secondaries.
1/100,000	 	1 kilometre.	50 metres.
1/20,000	 	100 metres.	20 metres.

The protractor, properly so called, is represented by the degree graduation along three edges of the front face. The point from which the rays are drawn is on the fourth (or zero) edge and is indicated by an arrow-head.

It will be seen that there are two sets of figures to these graduations—an outer set, reading from 0° to 180° and an inner set reading from 180° to 360° . All readings being made clockwise, this arrangement is for the purpose of plotting bearings, which are always measured from north by east.

62. Plotting Bearings with the Protractor

The angle denoted by any graduation on the edge of the protractor is that contained between the zero edge, *i.e.* the



FIG. 31.

edge joining 0° and $180^\circ,$ and a line joining the centre of the zero edge, marked with an arrow-head, to the graduation in question.

To plot any bearing between 0° and 180° from any point x, Fig. 31, draw a line xy through the point in the direction of north-true, grid or magnetic as the case may require. Lay the protractor with zero edge along this line with the arrowhead on x and the graduated edge to the *right*. Any bearing, such as 71 and 115, may then be marked off with a sharp pencil at p and q. Join xp and xq. To plot bearings between 180° and 360° , say 226° and 311° , set the protractor in a similar manner, but with the graduated edge to the *left*.

ALL R

It is not always necessary to draw a north line through the point from which bearings are being plotted. If north lines exist on the paper—such as parallel lines drawn or printed on sketching paper or meridian or grid lines on a map —it is often possible to lay the zero edge parallel to north and south by setting the protractor so that one of these lines cuts its bottom and top edge at graduations symmetrically placed, as in Fig. 32, or to set off the required bearing from



FIG. 32.

a convenient corner of a grid square, and transfer it by means of parallel rulers to the correct point.

63. Reading Bearings with the Protractor

Proceed in a similar way for the reverse process of reading a bearing from a map. To find the bearing of t from x, Fig. 31, join xt by a straight line, set the protractor as before with arrow-head at x and zero edge parallel to the north line; then read the bearing where the line xt cuts the graduated edge.

It may be noted that the reverse bearing * tx, i.e. x from t, may, if desired, be read at the same time on the other set

* If the bearing of B from A is t° , then the bearing of A from B is called the reverse bearing, and is equal to $t^{\circ}\pm 180^{\circ}$. If t° is less than 180° then the reverse bearing is $t^{\circ}+180^{\circ}$. If t° is greater than 180°, then the reverse bearing is $t^{\circ}-180^{\circ}$.

of graduation figures. Thus, if the bearing xt reads 94° , the bearing tx is 274° (Fig. 32).

64. Prismatic Compass

The Service Prismatic Compass of the dry type, Mk. VIII, is illustrated on Plate XVI. It is enclosed in a brass box, partly lacquered, with a lid C, containing an eccentric circular window W. Press open the box by means of the nail clip T, to the left of the handle. The compass is then seen, beneath a glass *cover*, to be of the "card" type, the needle being attached beneath the "card." The latter is of motherof-pearl, blackened in the centre save for an arrow, which is painted with a radium compound so as to be visible at night. The needle and its attached card are suspended on a pointed steel pivot, working in a jewelled boss seen beneath the cover. On the card or dial are two graduations, both increasing clockwise, the inner figured inwards from zero at the arrowhead, the outer and finer (degree) division figured outwards and starting from a zero at 180° from the arrow-head. Note further, that affixed to the inside of the box at the hinge is an index with a short vertical line L: this is named by mariners the lubber line.

By slackening a *clamping screw*, J, seen to the right of the hinge, the glass cover of the box can be rotated. Attached beneath the glass near its edge is a luminous radial index, known as the *direction mark*, shown as D; and exactly corresponding to this, interrupting the milling on the casing of the cover, there is an index or *setting vane* I, working over an external 5-degree graduation, the zero of which is at the centre of the hinge, corresponding exactly to the lubber line within. On a second and lower external graduation are shown the *points of the compass*, N under the hinge, N.W. (315°) near J on Plate XVI.

The compass card is normally motionless, being held clear of the pivot. It can be released by pushing the *slop* S away from the ring handle. It will be noticed that this stop is automatically brought into action by closing the lid, the stop being thus moved towards the ring by the *cam-clip* K on the lid. The design is to lift the card and its boss off the point of the steel pivot, which otherwise would be liable to damage when not in use.

A hair-line HVH is engraved vertically on the window. In the casing and at the ends of the hair-line are two luminous strips P for sighting at night. Observe that in these strips are two small holes H, which are drilled through the window casing; if the glass is broken in usage, a horse-hair or thread can be passed through these holes as a substitute for the hairline. A *longue* forms an extension of the lid; notice the





notch N at the end and the similar notch N on the ring handle.

Within the ring there is a small magnifying prism M, whose casing R is hinged to a slide in a shield screwed to the brass box. Tilt up the casing, thus revealing the eye-hole, above which the prism casing is slotted. When the hair-line HVH is vertical, the edges of this sighting slot ought to be seen to be parallel to it and are so in a well-constructed instrument.

It will be found that, for focussing the prismatic magnifier, it is necessary to draw up the prism; for this purpose a *slide* attached to the prism casing is provided to work in a groove in the shield.

65. Observing with the Prismatic Compass, Mk. VIII

To make an observation with the prism, pass the left thumb through the ring, place the left forefinger underneath the box, the right thumb on the stop and the right forefinger on the tiny stud A at the left of the hinge, actuating a *check-spring* in the box, which steadies the swing of the needle. The hair-line must be vertical. Observe it through the sighting slot, keeping it vertical against the object to be sighted and at the same time observe the readings of the card. At the centre of the swing press the check-spring stud A to bring the needle to rest. Then free it and allow the card to settle. The required bearing may then be read to a quarter of a degree if the hand be steady.

The compass may also be read directly but much less accurately by means of the inner graduation on the card and the lubber line. Open the lid out flat. The axis of the compass NLHHN is now the line passing through the notch in the ring, the centre of the compass, the lubber line and the notch in the tongue. Direct the axis towards the object and read the inner figuring on the card against the lubber line.

For use at night turn the glass cover until the setting vane indicates the bearing of the object on the external graduation of the box. Clamp the cover at this bearing by the screw J, and again direct the axis towards the object. It will then be seen that the luminous direction mark on the cover is exactly over the arrow-head on the card. The bearing; if you preserve the direction mark and arrow-head in coincidence and move in the direction of the axis, you will be moving in the line of bearing indicated by the setting vane. The direction of the required movement is clearly indicated at night by the luminous terminals of the hair-line.

Note, finally, the rubber ring on the base of the box which prevents the compass from slipping when on a smooth surface.
66. Liquid Prismatic Compass

The advantage of this type is that the card, being immersed in liquid, comes to rest very much more quickly than in the ordinary compass. It is therefore unnecessary to provide a check-spring and stop. In other respects the compass is generally the same as Mark VIII, but a few points of difference may be noticed.

The outer graduation on the card is transparent. A luminous patch on the bottom of the box beneath the erected prism emits rays which illuminate the graduation at night. On the glass which seals the liquid there is another luminous patch near the hinge; on this horizontal patch the lubber line is drawn. The setting circle is etched on the upper glass, whose cell is milled and rotates as in the dry type. The bearing is then set for night marching by bringing the desired reading on the upper glass into coincidence with the lubber line. (Note that in this graduation (5°) the short division traces correspond to the figures.) There is, however, a setting vane for use with the points of the compass, which form the single external graduation; corresponding to this setting vane there is, as before, a luminous direction mark on the movable upper glass.

Bubbles in the liquid may be trapped by turning the box over and slowly turning it back again.

67. Lensatic Liquid Compass

This compass may be met with in the service, but it is not a general issue and is not now manufactured. It is in appearance similar to the Liquid Prismatic Compass, but a small reading lens takes the place of the prism of the latter. The lens is mounted in a circular metal frame which is hinged to the case, and has a sighting slit cut above the lens. For reading, the compass is held in the same way as the Prismatic with the reading lens upright, and the hair-line on the window is sighted on the distant object through the slit in the lens holder and the bearing is read by means of the lens direct on the compass card opposite the lubber line. To adjust the focus of the lens its holder should be tilted slightly forward or backward as required. The compass card is graduated with one scale only; this is in single degrees—each 10 numbered—and reads clockwise from the North point.

The setting circle for night marching is fixed to the case of the compass, and is graduated anti-clockwise with the zero or 360° mark over the lubber line below the lid hinge. Each 20° graduation from zero is marked with a spot of luminous paint, the graduations 360° , 270° , 180° and 90° each being marked with two. The luminous setting index is carried on a metal ring inside the setting scale and is rotated by means of two small studs on it.

68. Compass Errors

1. Terrestrial Disturbances.—The presence of iron always affects a compass and great care should be taken to withdraw from any mass of iron when taking an observation. The following are minimum safe distances for visible masses of iron :—

Heavy gun Field gun and	telegra	 ph wi	res	 60 yards 40
Barbed wire Steel helmet				 10
Cap badge Box respirator				 in " slung " position

Electric cables and wires, dumps, railroads, tractors, corrugated iron hutments, steel or " rolled gold " spectacle frames and the like should be avoided.

Iron on the surface can be avoided, but when it lies below ground it presents a serious difficulty. Pipe lines below streets, or buried shells in battlefields, may be suspected, but in general there is no means of detecting masses of iron ore—the common cause of error—except by the behaviour of the compass itself.

If there is the least suspicion of disturbance the position of the compass should be shifted. The compass may then give a different reading, showing that there had been local disturbance, but, even if it does not alter, there remains the possibility of some widespread local magnetic field. The following test may be helpful although it is not conclusive.

Consider the forward (direct) and backward (reverse) bearings of the line AB in Fig. 32. The bearings AB at A and BA at B should differ by 180°; if they do not, there is presumably disturbance at A or B, or both.

Every ordinary compass has its individual variation, which may differ from the mean. Compass users should not rely too much on the magnetic variation as charted (Plate VIII), but should test their compasses on lines of known true bearing, say, between trig. points; and this should be done periodically. Bearings taken from a small scale map by a small protractor are barely good enough for this purpose; a good circular protractor and large scale map (1/20,000) are necessary.

In addition the line of known bearing may not be free from magnetic disturbance; hence comparisons at both extremities are desirable, and if possible a comparison should be made on two different lines. 2. Damaged Pivol.—Sometimes exposure or rough usage will corrode or damage the steel pivot on which the compass card spins. Not infrequently the card may be sluggish in its movement and may come to rest on an incorrect reading. (In this case it is clear that several observations of the same bearing may give different readings.)

When this trouble is suspected, bring the end of a nail or other piece of soft iron towards the pointer of the card from one side. If the pivot is in good condition, the pointer will swing easily towards, or away from, the nail and will return to its original position with an easy oscillatory movement when the nail is removed. If the pivot is causing friction, the pointer will remain stationary or move jerkily and will probably settle on a new reading when the nail is removed. This trouble seldom occurs with a liquid compass.

CHAPTER XI

ILLUSTRATION OF MILITARY REPORTS

69. General

1. The form in which the report of a Military Reconnaissance should be rendered and the matter which it should contain are given in the Field Service Pocket Book and Field Service Regulations. The value of a report will be greatly increased, however, if it is freely illustrated by maps, field sketches, panorama drawings or photographs. Such illustrations are of no value unless they make the subject matter of the report clearer to the reader and save writing.

2. An officer, before proceeding on a military reconnaissance on active service, must secure the best available map. In peace, and in a friendly country, he should obtain all the available topographical information about the area over which he is to work. He should also study all existing handbooks of the locality to avoid duplicating information.

3. From a topographical point of view the report should include details of all natural features which may affect tactics, movement, camps or billets, and supply. It should include also a statement of the effect of seasonal changes of weather. For the most part the military aspect of these subjects is dealt with in other manuals. There remain two subjects to which further reference should be made. The first is the classification of roads, rules for which are given in Section 80. The second is geology. Without any particular knowledge of this subject, observation and information may make it clear what soil becomes sticky and heavy for cross country traffic, or where rocky outcrop or broken surface may make it difficult to find landing grounds. A geological map will then show where similar conditions are likely to be found. Similarly, on the important questions of boring for water and of finding good stone for road making, useful information may result from observation guided and helped by such geological information as can be procured in advance.

4. A map is never perfect and rarely up-to-date. Even when a large scale map exists, much information must be added before it can become a full illustration to a military report. In cases where topographical maps exist, should the scale be large enough, it will only be necessary to add such information as is required, but care must be taken to ensure that over-crowding does not spoil its clarity or render it useless as an illustration. Should the scale be small, enlargements can be made of those areas of special interest. These enlargements should omit everything which is irrelevant, and should then be amplified by the addition of the special detail and information required by the report.

5. In cases where no maps exist, the information required in a report must be illustrated by field sketches, panoramas, thumbnail sketches and photographs. Traverses are especially useful for road or river reconnaissances. No hard and fast rules can be laid down on this subject, and in carrying out a reconnaissance, the most suitable form of illustration for the report must be chosen.

The methods of field sketching and traversing are described in Part III.

70. Panorama Drawings and Landscape Sketching

Panorama drawing is the art of reproducing on paper the view obtained by an observer from any given point. Such a drawing, intelligently produced, is of the greatest value in illustrating a report and thereby adding to its clarity. No artistic sense is required, but practice is essential.

The principles to be observed in making a panorama are as follows :---

- A definite proportion of the time available for producing the panorama should be spent in the careful study of the ground with the naked eye and with binoculars. This should be done before ever pencil is put to paper.
- ii. The principles of perspective must be followed as far as possible. These, for military purposes, may be

summed up by saying that the further away an object is in nature, the smaller it appears to be, and the smaller it should be represented on paper (Fig. 33). Parallel lines receding from the observer therefore appear to converge, their ultimate meeting point being called the vanishing point.

This vanishing point may be assumed to be always on the same plane as that on which the parallel lines rest. Thus railway lines on a perfectly horizontal surface, receding from the observer, will appear to meet at a point infinitely far away on the horizon, which is the eye level of the observer. If the plane on which the railway lines lie is tilted, either up or down, the vanishing point appears to be similarly



raised or lowered. Thus the edges of a road running uphill and away from the observer will appear to converge to a vanishing point above the horizon, and if running downhill, the vanishing point will appear to be below the horizon.

- iii. Absolute simplicity is essential in a military panorama. No line should be drawn on the paper without a definite idea as to what that line is to represent and as to the necessity for it.
- iv. All natural objects, such as buildings, trees, hedges, roads, should be shown by conventional outline only. This means that the desire to represent what is actually before the observer should be subordinated to the use of conventional shapes which are easy to draw and convey the required impression. Unnecessary shading must be avoided. A light "hatch" may, however, be employed to distinguish wooded areas from fields where necessary. Any attempt to

combine artistic with military value will prove unsatisfactory.

v. A firm continuous line should be used throughout. Feathered and undecided lines must be avoided.

Once the principles to be employed have been thoroughly grasped, the question of method may be discussed. The following should be available :—a service protractor, or a suitably graduated ruler, a length of string, a pencil capable of producing both fine and firm black lines (an "H," say), a rubber and suitable paper—squared for preference.

71. Extent of Country to be Included in a Panorama

1. Before commencing a panorama, the extent of country to be included must be decided. Military conditions will usually provide the answer. It will be found, however, to start with, that about 30 degrees of arc is a maximum suitable area to draw on a single sheet and that, should larger scope be required, two panoramas, subsequently to be stuck together, should be prepared.

2. A convenient method of making a decision as to the extent of the country to be drawn on each panorama is to hold a service protractor about 11 inches from the eye, to close one eye and consider the section of the country thus blotted out by the protractor to be the area to be sketched. The extent of this area may be varied by moving the protractor nearer to, or further from the eye, and once the most satisfactory distance has been selected, it must be kept constant by means of a piece of string attached to the protractor and held between the teeth.

A service protractor held 11 inches from the eye subtends an angle of approximately 25°.

72. Framework and Scale

1. The next step is to fix on the paper all outstanding points in the landscape in their correct relative positions. This is done by denoting the horizontal distances of such points from the edge of the area to be drawn and their vertical distances above the bottom line of this area, or below the horizon. The horizontal distances in the picture may be obtained by lowering the protractor and noting which graduation on its upper edge coincides with the feature which it is desired to plot: the protractor can then be laid on the paper and the position of the feature marked above the graduation noted. Vertical distances may be similarly obtained by turning the protractor with its long side vertical. Thus the exact position of any piece of detail may be plotted accurately upon the paper. Squared paper, as supplied in Army Book 153, will be of assistance to the beginner.

2. In all types of country, with the possible exception of mountainous areas, the vertical scale of a panorama should be exaggerated in relation to the horizontal scale, in order that minor folds of ground may be easily distinguished. A suitable exaggeration is that of 2:1, which means that every vertical measurement taken to fix the outstanding points in the landscape should be doubled, while the horizontal measurement of the same points will remain the same.

73. Detail

When all the important features have been plotted on the paper in their correct relative positions, the intermediate detail is added, either by eye or by further measurements from these plotted points. In this way the panorama will be built up on a framework as shown on Plate XVII. All the original lines must be drawn in lightly and, when the work is completed, it must be examined carefully and compared with the landscape to make sure that no detail of military significance has been omitted. The work may now be drawn in more firmly, bearing in mind that the pencil lines must become darker and firmer as they approach the foreground.

74. Conventional Representation of Features

In completing the sketch, the following methods of representing natural objects in a conventional manner should be borne in mind.

Outstanding Points.—All outstanding points which might readily be selected as a reference point when describing targets, such as oddly shaped trees, outstanding buildings, towers, etc., should be carefully drawn and made to represent their natural appearance if possible.

They must be accentuated with an arrow and a line bearing a suitable label, e.g. "Outstanding tree with large withered branch," or "Square embattled tower," and the map reference given where possible.

- Rivers.—A double line with its width diminishing as it recedes should be employed. Where the actual water's edge is to be shown, the line may be slightly waved.
- Trees.—Trees should be represented by outline only. Some attempt should be made to show the characteristic shape of individual trees in the foreground.
- Woods.—Woods in the distance should be shown by outline only. In the foreground the tops of individual trees may be indicated. They may also be shaded, the depth of



Panorama Drawing 1st stage shewing points whose positions and protractor can be used as a framework on which the read



ns fter being plotted from measurements with a relaining detail may be hung.



shading becoming less as the distance from the observer increases.

- Roads.—Roads should be shown by a double continuous line, diminishing in width as it recedes.
- Railways.—Railways are indicated in the distance by a single line with the telegraph poles shown by vertical ticks: in the foreground as a double line with small cross lines (indicative of sleepers) to prevent confusion with roads.
- Churches.—In simple outline sufficient to show whether tower or spire is denoted.
- Towns or Villages.—Definite rectangular shapes denote houses, with indication of towers, factory chimneys and outstanding buildings where they occur.
- Cuttings and Embankments.—May be denoted by the usual map conventional sign—a firm line with ticks at right angles to it, diminishing in thickness from top to bottom.
- Moorland or Heath may also be shown by the usual map conventional sign-groups of short upright ticks.

75. Other Methods

1. The foregoing method of drawing panoramas will be found the easiest and most encouraging for a beginner. There are, however, other methods. A simple device which will greatly assist in panorama drawing can be made by taking a piece of cardboard and cutting out of the centre of it a piece of the approximate dimensions of a service protractor: a piece of photographic film, previously cleaned in warm water and quite clear, is then pasted over the hole so made and on the celluloid are drawn firm lines making a grid of squares about 1/2" wide. The effect thus obtained is that of a ruled celluloid window in a cardboard frame, through which the landscape may be viewed. The paper on which the drawing is to be made is ruled in a similar manner to the window. If the frame be kept at a fixed distance by a string held in the teeth, the detail seen can then be transferred to the paper square by square.

2. An alternative method is to divide the paper into areas by vertical lines denoting a fixed number of degrees of arc, and then to plot the position of important features by taking compass bearings to them. This method is accurate, but slow.

76. Finish

1. The finished panorama should be clear and simple (Plate XVIII). A few touches of colour may assist in making its meaning clearer. Rivers may be tinted blue; roofs red; and roads brown. No attempt must be made to produce an artistic effect by the insertion of unnecessary detail.

2. When the panorama is complete, the following information should be added :---

i. Map reference of the observer's position.

- ii. Bearings, names and, where possible, the map references of important points, towns, villages, etc., should be written above the panorama, and lines drawn into the work to indicate the position referred to.
- iii. The bearing of the centre of the panorama from the point of observation.
- iv. The name, rank and regiment of the observer.
- v. The date, time and notes as to the weather conditions.
- vi. Any indication of troops on the panorama should be shown in the conventional colours—*i.e.* blue for hostile and red for friendly forces.

77. Panoramas for Artillery Use

1. In addition to the view that can be seen from the observation post, a panorama for artillery purposes should show a central line drawn through some conspicuous point in the zone overlooked, together with a network of vertical lines showing the lateral angles right and left of it. The angles of sight to probable targets or target areas should also be shown.

The lateral angles can be measured with the director, prismatic compass or graticuled glasses.

2. Artillery panoramas are useful for three purposes :

- i. As a means of reporting to an artillery commander the view that can be seen from an observation post.
- ii. As an aid to an artillery commander in the indication of targets for observed fire to his subordinates. Such a panorama need only show a few prominent reference points drawn clearly and unmistakably.
- iii. As a record of artillery data on a battery front. The lateral and vertical angular measurements and ranges as shown on the panorama will not normally be the same as those required for executive fire orders, since the point at which they are made is rarely that occupied by the battery.

3. The measurements, of which the panorama is a record, are used in conjunction with the artillery board to fix the position of certain prominent points in relation to the battery position. Switches, angles of sight and ranges from the battery are measured from the artillery board and tabulated









on the panorama, which is then an assistance to the battery commander in engaging targets in the zone depicted.

4. Plate XIX shows the same view as Plate XVIII treated more conventionally for artillery purposes, and amplified by a table of the relevant data. It should be noted that an indication of the reliability of the information so tabulated must be given.

The figures given in this Table are not necessarily accurate. The diagram is to illustrate the method to be employed.

78. Thumbnail Sketches

1. Small sketches, such as shown on Plate XX, should be used to illustrate descriptions of details of road turnings, bridges, fords, watering points, wells, sidings, buildings for demolition, detours in a road, etc. For example, in a road reconnaissance where the only available map is on a small scale, such as 1/250,000, it is simpler to show an intricate turn in a village by a sketch such as Fig. 1, Plate XX, than by making an enlargement of the map and adding the necessary detail. Or again, in a route reconnaissance for a column moving across country, the point where a change of direction is to be made can be given by a sketch, as in Fig. 2, Plate XX, which shows the relative position of detail at that point, such as two houses in line or the relation between a group of trees and some feature in the distance.

2. The principles and methods of panorama drawing apply equally to the preparation of thumbnail sketches of opsitions of special interest. The sketches are executed by eye after the main proportions have been lightly sketched in by measurement, either with the protractor, as in panorama drawing, or by holding the pencil at arm's length and marking off distances on it with the thumb.

Simplicity should be the key-note of all such sketches.

79. Photographs

Liberal use may be made of a camera in a military report. Such a camera should be small and equipped with a good lens to enable photographs to be enlarged subsequently. Films are obviously preferable to plates. All photographs taken should be listed and numbered as they are taken and all references to them in a report should quote their identification number. Cameras will be found most useful for the illustration of local detail, but will be of little use for distant views.

80. Classification of Roads

 The bulk of information required about roads for military purposes can generally be shown on a map or sketch. To enable this to be done, roads will be classified by letters as regards width and by figures as regards surface and foundations, viz. :---

" A " roads, those wide enough to take 2 streams of traffic of the nature denoted by the subsequent figure.

- " B " roads, those wide enough to take one stream of traffic of the nature denoted by the figure, but on which individual and occasional vehicles can pass the stream.
- "C" roads, those wide enough to take one stream of traffic of the nature denoted by the figure, but on which passing is impossible except on certain definite passing places.
- No. 1 category roads capable of taking heavy M.T., viz. 3-ton lorries, heavy guns, etc.

No. 2 category roads capable of taking light M.T. up to 1-ton lorries.

No. 3 category roads capable of taking H.T. only.

No. 4 category roads capable of taking pack transport only, or bridle paths.

The combination of these factors gives the following results :---

	Heavy M.T.	Light M.T.	H.T. only.	Pack Trans- port.	
		1	2	3	4
Two streams	А	A 1	A 2	A 3	A 4
One stream with oc- casional passing B		BI	В 2	в 3	B4
One stream only	С	C1	C 2	C 3	C4

Thus, for example, a road sufficiently wide to take one stream of heavy M.T. traffic only will be described as C. I, and this classification will be written on the map or sketch, which illustrates the road report, alongside the road to which it refers.

2. In addition, when the surface of a road deteriorates in the wet season, its classification at that period will be shown in brackets. For example, an unmetalled road in a semitropical country, capable of taking 2 streams of light M.T. in the dry season, and only H.T. in the wet season, will be shown on the sketch as A 2 (A 3).

3. It is also of value to write after the classification, the type of metalling employed, viz: granite, laterite, etc., thus giving an indication as to the wearing qualities of the road under continuous traffic.

4. The reporter should use his common sense and put in illustrative form all the information possible, in order to save time for the officer who has to make use of the report.

PART II-PHOTO READING.

CHAPTER XII

PHOTO READING

81. General on Types of Photographs

Photographs taken in the usual way from a ground station are used to illustrate the view from O.Ps. or to accompany reports. They reproduce the view normally presented to the eye of the observer, objects in the foreground being naturally larger than those in the distance. A photograph taken from an aeroplane with the same horizontal axis would show little but sky. Air photographs are taken therefore with the camera depressed below the horizon (obliques) or pointing straight downwards (verticals). Neither appear quite natural to the eye. The difference can be visualized by thinking of a few chessmen on a chessboard. Putting the eye at the level of the board, the chessmen are seen in elevation (ordinary ground photograph). Looking sideways and from above, at an angle of about 45°, the chessmen are foreshortened, and the squares of the chessboard are seen in perspective (obliques). Looking directly down on to the centre of the board the squares look correct and are no longer in perspective, but the chessmen are seen in plan only (vertical).

82. Value in examining Ground

1. The value of obliques and verticals in the examination of ground is seen clearly from the example of the chessboard. The oblique shows more of the ground than can be seen from any ground station, and it shows hill features and objects in a way more or less familiar to the eye, although not so well as from a ground station. It is useful in showing natural features such as hills, ravines, defiles, and in finding the best covered line across country. The vertical shows the ground in plan, and no detail, except under trees or artificial cover, escapes notice. It shows, more clearly than the oblique, local features, such as water, marsh, and plough and the details of towns, villages, railways, roads, tracks, canals, earthworks, etc., but gives practically no clue to hills, valleys, and contours generally.

2. When photographing from a ground station it is possible to take a series of overlapping views, which, joined together, form a complete panorama. The same would be possible for "obliques" from the air, if a sufficient number of cameras could be used simultaneously and at the same angle to the horizon. With a single camera it is not possible, because the aeroplane travels too fast (and therefore too far) between exposures. Verticals, however, being nearly (though not quite) correct in plan can be joined up to make a combined picture, or mosaic of a large area. Mosaics provide a useful guide to country, but, like all vertical photographs, do not show heights.

83. General on the Stereoscope

In the preceding paragraphs photographs were considered singly (even in mosaics there is only one single picture of any one small area). In this single form they represent what one eye would see from the position of the camera. Normally, however, we use two eyes, and the combination of the views so obtained enables us to appreciate shape and form. The distance between pupils (about $2\frac{1}{2}$ inches) is the base of the human range finder. The same stereoscopic effect (but extending to much greater distances) is obtained from two photographs of the same object, taken from different points of view,* and seen through a stereoscope. The photographs must, however, be taken at about the same distance from the ground, and at about the same angle to the horizon. Supposing that two verticals are taken at about a distance of 1 mile from each other in the air, then the "overlap" between them (about half of each photograph) will show the same country from two points of view. Looked at in the stereoscope this overlap is seen in the form of a raised model, on which hills and valleys, as well as ordinary detail, are equally visible. and in which the respective advantages of oblique and vertical

84. Types of Photographs

i. Ground photographs (including panoramas). These require no further explanation.

ii. Obliques-

Always used singly.

iii. Verticals-

(a) Individual prints.

(b) Made up in mosaic form.

(c) Used in pairs with the stereoscope.

 No stereoscopic effect is possible without different points of view.
For example, two copies of a map or two identical photographs can give no stereoscopic effect. With i and ii it may be possible to use the stereoscope, but so rarely as to make it unnecessary to go further into the question. On the other hand, with iii a stereoscope is easy to use, and adds largely to military value.

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85. Use of Maps in Photo Reading

Any photograph, of whatever type, deals with a small portion of the ground, and is undefined in position, scale, and orientation. Like the thumbnail sketches which accompany a report, photographs must be studied with the map. The map is the authority for distances, bearings and the general tactical features of the ground. The photographs add local information, both of topography and of the dispositions of the enemy. Maps and photographs are therefore complementary and must be used together.

86. Obliques

Obliques represent a sector bounded by lines which start at the camera and open out (at an angle which may vary from 40 to 60 degrees) to the horizon. Each oblique, therefore, illustrates the view from a single point and is not correct for any other point. It is useful, as a general guide, at any place within its sector, but must not be taken as correct in direction or relative distance, except from the point above which the camera was exposed. That point will never be known accurately, however, and it becomes more than ever essential to use the map in connection with the photograph. Obliques are most useful in orienting the line of attack. Since the view of an ordinary oblique is very similar to that which might be seen from the top of a mountain, no special instruction in its use is necessary. If, however, the oblique is depressed much below the horizon, objects will tend to appear more in plan than in elevation, and the remarks of the succeeding paragraphs on verticals will be found useful.

87. Verticals

Verticals, as being easiest to take and most useful for all topographical and military purposes, form the bulk of photography on service. They show the ground from an unfamiliar point of view, and require some special explanation. It must be remembered that all detail appears in plan, and if one or two verticals are compared on the ground with the country represented, little difficulty will subsequently be found in identifying objects. Verticals are used for the following main purposes :--

i. Examination of tactical features-

In some cases photographs are used as a substitute

for large scale maps. In others they are studied for the particular needs of different arms, *e.g.* for identifying obstacles to tank movement.

ii. Intelligence-

Commonly dealt with under the heading of "interpretation," this point will not be enlarged upon. It is a matter of common sense, training and knowledge of contemporary tactical method.

iii. Mapping-

Of interest to technical troops only, except in so far as it is dealt with for sketching purposes in Chapter XVIII.

88. Data required for Use of Verticals

1. To extract the full information from a vertical, the observer, in addition to being familiar with the appearance of objects photographed from above, must know the following facts for each individual photograph :---

i. The position, or area, illustrated.

ii. The scale.

iii. The orientation.

iv. The serial number (for reports or for further demands).

v. The direction of the light.

2. To provide as much as possible of this information the following data are given in the margin of each photograph taken with that type of camera known as the F.8. (Plate XXI.)

i. Time of exposure.

ii. Height of exposure (above level of aerodrome).

iii. Date.

iv. Focal length of lens.

v. Unit taking photograph.

vi. Levels.

vii. Serial number of photograph.

viii. Map Reference and north point.

3. If old patterns of camera (not equipped with the "data" panel of the F.8) are used, information is generally inscribed by hand on the negative (Plate XXI).

89. The Position of the Area Photographed

1. It is sometimes exceedingly difficult to "place" a photograph on the map. The photograph is generally at a much larger scale than the map, which itself may be out of date or so much generalized as to afford little clue to the position of individual prints. If a series of photographs is available

PLATE XXI.

DATA PANEL F 8 CAMERA.

DATA ON OLD TYPE PHOTOGRAPHS.



 Unit taking photograph and serial No. of photo.
Map sheet and approx. refer-ence of area photographed.
Date and time of photograph.
Focal length of camera and altivide. Point. ż

altitude.

Approx.

XIIE. 0.62.72.

LENS F# 7 F8/'6' SOR PY 29:10: 28

Camera level bubbles.

Serial No. of photograph.

Altitude at time of exposure.

Map Sheet and approx. reference of area photographed. Approximate N. Point

Type of Camera and Focal Length. Unit taking photograph. Date of photograph.

Time of exposure.

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N

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proceed as follows :- Examine on the map the area over which the aeroplane was photographing. Pick out one or other of the following :-

i. Railways.

- ii. Roads with characteristic bends, corners or junctions with other roads. A long and more or less straight stretch should be chosen.
- iii. Rivers and canals of well-marked shape, and sufficiently straight and long.

Identify a photograph of some portion of the chosen object, and then proceed to follow along the same feature until three or four photographs have been correctly placed and the scale has been roughly gauged. Now look on the map for towns, villages, lakes and woods in reference to the railway, river or road originally chosen, and place other photographs roughly in position until all have been located.

2. With a single print it will be found best to choose some large and well defined object in the photograph, and to look for the same on the map.

90. Scale

1. Only in perfectly flat country will the scale be constant over the whole area. In mountainous country the scale will vary, because the top of a mountain is nearer to the camera than its base, and appears therefore at a larger scale. In undulating country the variations in scale will not be noticeable for practical purposes, but, supposing that the general level of the country is higher on one edge of a photograph than on the other, the effect may be very marked. For example, if a straight line of railway appears on the left edge of a strip of several photographs, and the country rises from it to a line of hills on the right edge, then, if fitted together, the resulting mosaic will bend to form an arc of a circle, and the railway, actually straight, will bend at each join. In no case, then, can the deduced scale be anything more than an approximation.

2. The best method of obtaining the scale is to compare the distance on the photograph between two objects with the distance on the map (or ground) between the same two objects.

3. The scale may be obtained approximately by measuring on the photograph the width or size of objects such as a road, railway or house, whose actual dimensions are known.

4. The R.F. of the scale may be obtained from the formula focal length of lens (F) (Fig. 34).

height (H)

Both of these factors are given in the "data" panel of the F.8 camera (see Sec. 88), but both must be in the same unit—example—F. (focal length) 10 inches, H. (height) 12,000 feet. Then scale is $\frac{10/12}{12,000}$ or $\frac{1}{14,400}$ (about 4 inches to the mile).

The scale thus obtained is that of the ground at the level of



the aerodrome, and may, or may not apply to the area photographed.

[^] This R.F. will be the scale of the photographic negative or of a contact print. If the photograph has been enlarged the scale is enlarged in the same ratio.

91. Orientation

1. Where photographs have been "placed" on the map, the orientation follows as a matter of course. Where they have not been placed shadows must be studied in conjunction with the time of exposure.

2. It is often difficult at first to identify the direction of shadow. For example, an avenue of poplar trees will cast shadows which are often taken to be the trees themselves (the latter appearing as small dots at the ends of the shadows.



Direction

of light during examination

EXAMPLE OF CONTRARY EFFECT PRODUCED BY EXAMINING PHOTOGRAPH UPSIDE DOWN.



Photograph upside down.



Photograph held correctly.

The mounds in the top photograph are now seen to be excavations and the railway cutting to be an embankment. The Tower at A, and its shadow, clearly indicate the direction of light in the photograph. The photograph must be held so that this direction corresponds to the direction of light during examination.

(To face page 85.

easily identified in the stereoscope but difficult to pick up on individual prints). Nevertheless trees and houses are the safest guide to direction of shadow. If they do not exist on the photograph, look for bridges or telegraph poles. Only a rough orientation can be obtained in this way, and an approximate idea of the position of the sun at the time of exposure will suffice. Cuttings and embankments are dangerous as a guide to shadow because, as explained in Section **97**, para. 6, they may be confused with each other and wrong deductions may be drawn.

92. Direction of Light

At the time of exposure the sun casts shadows in a direction due to its position at that moment. In studying the photograph the light from the window or artificial source must be made to fall on the photograph in the same direction as did the sun's rays on the ground. If shadows appear to point towards, instead of directly away from the light, the effect is contrary to nature and embankments look like cuttings, and spurs like valleys (Plate XXII). This rule, then, "reproduce the lighting conditions of nature," applies to the examination of any vertical photographs (single, mosaic, or stereoscopic pair), and misleading or inferior results will inevitably occur if it is not followed (Section **97**, para. 6).

93. The identification of Objects on the Photograph

The two main aids to identification are :--

i. The shape.

ii. The tone, or shade of grey, in which the object appears.

94. The Shape

On a photograph taken from the ground, and, to a less extent, on an oblique, objects appear, as they are seen by eye, in elevation. On a vertical they appear in plan. A map shows objects in plan by a number of carefully designed conventional signs, and these same objects can often be identified on the photograph from their similarity to the appropriate conventional sign. Thus railways, canals, roads, rivers, houses, etc., present little difficulty. As a rule, artificial objects are easier to identify in this way than natural objects, because they are bounded by straight lines or by regular curves.

It is for this reason that camouflage aims at breaking up regular lines and curves, both of objects themselves, and of their shadows. Some natural objects such as rivers and streams, with their winding courses, or small woods or spinneys are easily identified. In case of doubt look at the conventional sign list, which may give an immediate clue.

95. The Tone

The tone or shade is due almost entirely to the amount of light which is reflected by the object to the camera. Colour may sometimes affect the tone slightly, but its effect is relatively so small that it may be neglected. The reflection of light itself depends on a number of contributing causes, such as the position of the sun, the texture of the surface, and the strength of the wind.

96. Reflection of Light

1. The more light reflected by an object towards the camera, the whiter does it appear on the photograph. The amount of light reflected depends on the nature and texture of the surface, and upon the angle which that surface makes with the sun's rays and the photographic plate.

2. Light striking a perfectly smooth surface at an angle of E (angle of incidence) is reflected at the same angle (Fig. 35); if the camera lies in the path of the reflected light the object will appear white on the photograph. Smooth reflecting surfaces will appear dark, however, if the light is not reflect light in all directions and appear intermediate in tone, because some of the reflected light finds its way to the camera.

3. Smooth water, which reflects most of the direct light falling on it, may be taken as a simple example. In Fig. 35, the angle OLA represents the range of a camera taking a vertical photograph. Light will only be reflected on to the

photograph when E is equal to, or greater than $90^{\circ} - \frac{\text{OLA}}{2}$.

 $\frac{OLA}{2}$ depends on the camera in use, but will not be more than

30°. Therefore the sun will only be reflected on to the photograph from smooth water, when at an altitude of 60° or more, and it will then appear as a white patch, merging off gradually into black or dark grey.

4. But all reflecting surfaces are not level and, no matter what the altitude of the sun may be, there may be some that will reflect light on to the photograph; *e.g.* glass roofs, roads on hills, etc.

5. Rough and irregular surfaces may be considered as consisting of a number of reflecting facets of various sizes, inclined at different angles to the level. The nature of the object will determine the quantity and size of the facets, and the possibility of any of them reflecting light direct to the camera.

6. Objects that reflect much light to the camera will appear

lighter on the photograph than their colour would appear to warrant. Examples will be found in Section 97.

7. The preceding paragraphs will explain why tracks are so



FIG. 35.

easily picked up on air photographs. The earth, grass or vegetation is crushed flat so as to alter the reflection of light, whilst, in many cases, the straightness and evenness of the track or path gives an additional clue.

97. Examples of the appearance of Topographical Features on Vertical Photographs

1. The following paragraphs are intended to give a general idea of the appearance of common natural and artificial features. Many of the same features are illustrated also on Plate XXIII, which should be studied in conjunction with this section.

2. Roads, Tracks and Paths.

Roads are, in general, of uniform width and run in straight stretches of varying length with regular bends. Sharp bends will usually only be found in broken country where embankments, cuttings and bridges are also more frequent. The width of roads cannot be measured with certainty, as the edges, which are least used, merge into, and are lost in grass margins.

Tarred roads, owing to their colour, should appear black, but, as they reflect indirect light, appear dark grey. Where the sun is reflected direct to the camera the road appears white, shading off to grey again on each side of the reflecting point. Usually there is a narrow light strip down each side of the road, due to the accumulation of dust on the least used parts.

Macadamized roads appear light grey. The surface, though rough, is flat, and therefore reflects indirect light. The rough surface does not reflect the direct rays of the sun so much as a tarred road, and never appears so dazzling white.

Unmade roads, tracks and paths appear in the same tone as macadamized roads, but are less regular. Wheel tracks



appear as two light lines. A central line of slightly lighter tone (see Fig. 36) implies horse traffic.

3. Railways.—Railways are distinguished by straight lengths and regular curves (more regular than on roads). Width is uniform and embankments and cuttings are frequent, especially in hilly country. In general the tone is a medium grey due to the broken surface and shadows of the ballast. On clear photographs, and those taken at a low altitude (e.g. 5,000 ft.), the shadows cast by the rails may be seen.

4. Telegraph poles.—These almost invariably occur along a railway and frequently along roads, but can seldom be directly identified on a photograph, except by their shadows. Strong sunlight and a suitable background are wanted to show them up. They may sometimes be shown up by small white spots, indicating ground round each pole that has not been touched by cultivation. Shadows or spots will be at regular intervals, and probably ranged in a series of straight lines.

5. Bridges.—These will be looked for at the crossings of roads (tracks and railways), and water, or at sharp dips in the ground. They are not always straight, but are generally uniform in width and probably cast a shadow. Most bridges have parapets and the tops of these, usually smooth, appear as light grey or white lines. Outward projections from the parapets indicate piers.

6. Embankments and cuttings are regular in shape and can be identified by their shadows, see Plate XXII.

If the slopes away from the light are in shadow they appear dark ; if not in shadow they reflect but little light to the camera and appear darker than the surrounding ground. Slopes facing the sun reflect more light to the camera and appear light grey or white.

7. Cliffs, quarries and steep hills.—The same considerations apply here as to embankments and cuttings. Shape is, however, irregular.

8. Water.

Smooth water, except where it reflects the direct sun's rays into the camera (Section 96), appears dark grey or black, as it reflects only indirect light. If the water is shallow, with a light or weedy bottom, it reflects more light and appears lighter in colour. It is not easy to be sure whether mud or sand is dry or covered by shallow water.

Rough water, either sea or stream, presents many reflecting faces to the light and white patches appear on the photograph. If water is ruffled by a breeze these patches tend to appear in lines, whereas in surf or broken water the patches are irregular.

Canals are smooth, except when touched by a breeze, and appear dark grey or black. They are uniform in width and follow the contours. Frequently a tow path appears as a light line along one side. Locks may be identified by bars of light and shadow across the water.

9. Trees, bushes, scrub and hedges.—These, with mixed reflection and shadow, appear in shades from medium grey to black. Thus a wood appears patchy, because some trees reflect more light than others, and tend to counteract the effect of colour and shadow. Isolated trees and bushes appear as circular dark spots at the end of slightly lighter shadows. These shadows assist in distinguishing clumps of trees from ponds and water. The stereoscope shows up trees unmistakably.

Orchards are distinguished by the regularity in spacing of the trees.

Scrub, usually mixed with grass or sand, appears as darker patches on a lighter tone. If the scrub is thick, shadows will be visible.

Hedges appear as dark irregular lines with, or without shadow according to their height.

10. Grass, heath and swamps (marsh).—Viewed from above grass presents a broken surface reflecting little light. Its appearance therefore depends partly on its length, and consequent shadow, and partly on the wind which alters the angle of reflection. Short grass appears lighter, as it presents a better reflecting surface, and may show the soil underneath. In general, grass is between light and medium grey, and patches of coarse grass, or heath, are darker, with a mottled appearance. Heath merging into bog or marsh is in darker shades of grey with the same mottled appearance.

11. Crops and cultivation.—With crops the same arguments apply as with grass. The tone of young crops is light on account of the reflection from the ground. As they grow so does their tone darken with lighter patches where beaten down by wind and rain. Ripe upstanding crops usually appear light in tone.

Roots, beans, etc., appear in varying shades according to age and lighting and often present a mottled appearance due to the contrast between reflecting leaves and shadow. The regular lines of cultivation give a "ruled" appearance to the photographic image. A field of well-grown mangolds appears light, and sometimes white, owing to the predominating effect of reflection from the large shiny leaves.

Tilled and dressed soil appears a light grey in most cases. Fresh plough varies in tone from white to dark grey according to the lighting and the nature of the soil, but is usually quite distinct from neighbouring unploughed land.

Heavily cultivated country appears as a patchwork of varying shades and is difficult, and frequently impossible, to classify.

12. Soil, sand, and rocks.—In general bare ground appears light, as do unmade roads. Chalky soil is indicated by white patches, clay is generally darker.

Sand, providing a comparatively smooth surface, appears light; deeper toned patches may indicate slopes.

Rocks vary from white to dark grey, according to surface. Wet rocks, facing the sun, reflect the light and appear white. Shadows are deep and well defined.

13. Fences, ditches and walls.—These are difficult to distinguish on photographs taken at usual heights, as the scale is not large enough to show them up. They may be found from their shadows when the sun is low. The stereoscope shows them up at once and distinguishes one from another.

14. Buildings.—Owing to their flat surfaces, buildings generally produce high lights. Shadows are clear and well defined. Cottages are easily picked out after a little practice, but may, at first, be confused with haystacks. Isolated buildings are frequently brought to notice by tracks leading to them.

15. General.—The foregoing examples are hints, and only hints, on the photographic appearance of natural objects. There are two factors governing the appearance of objects

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12 P

REFERENCE.

ugh Pasture. niferous Wood. ugh heathy pasture with scattered trees. ciduous Wood on hillside. attered Deciduous Trees. ath and gorse on rising ground. cky tors. oken cliffs. tuary and Tidal mud flats. ver. ver mouth and bar. a beach (12A groins). alk downs. alk Cliffs. llow Copse. in Road, tarred. condary Road, macadamised. Road. ad Bridge over River. lvert under Railway. ilway. (21A on Embankment, 21B in Cutting). ad Bridges over Railway. ilway Station. ods Sheds and Railway Sidings with trucks. rm house, buildings and yard. stages. urch. use and gardens in park. otments. ast guard Station. m. alk pit with cart track. ptpaths on chalk. ick through Wood. ver. pasture eaten off and sun dried. pasture from which hay has been carried. atoes. shly cultivated and sown land. ugh (dark strips show fresh ploughing). ngolds (light appearance due to reflection from the very smooth leaves). vn grass. manent pasture. manent pasture much trodden. id. ld of grass partly cut. n nearly ripe and much beaten down. ter meadows. ep in turnips (the light parts show where the roots have been eaten off). wing roots (the young plants do not conceal the ridge and furrow). wing wheat (green). ns cut and shocked. bble (53A Corn Stacks). eat, A-Standing, B-Cut and lying in sheaves, C-in Shocks. nding Barley. ver cut and partly raked. hghing on chalk, the dark strips may indicate fresh ploughing.

THE APPEARANCE OF OBJECTS ON VERTICAL PHOTOO




Plate XXIII.

GAPH-WITH KEY.



Plate XXIII.

REFERENCE.



- Rough Pasture.
- 1. Coniferous Wood. Rough heathy pasture with scattered trees. 2.
- Deciduous Wood on hillside. 3.
- 4.
- Scattered Deciduous Trees. Heath and gorse on rising ground. 5.
- 6.
- Rocky tors. 7.
- Broken cliffs. 8.
- Estuary and Tidal mud flats. 9.
- River. 10.
- River mouth and bar. 11.
- Sea beach (12A groins). 12.
- Chalk downs. 13.
- Chalk Cliffs. 14.
- Willow Copse. 15.
- Main Road, tarred. 16.
- Secondary Road, macadamised. 17.
- By Road. 18.
- Road Bridge over River. 19.
- Culvert under Railway.
- Railway. (21A on Embankment, 21B in Cutting). 20.
- 21. Road Bridges over Railway.
- 22. Railway Station.
- Goods Sheds and Railway Sidings with trucks. 23.
- 24. Farm house, buildings and yard. 25.
- Cottages. 26.
- Church. 27.
- House and gardens in park. 28.
- Allotments. 29.
- Coast guard Station. 30.
- Barn. 31.
- Chalk pit with cart track. 32.
- Footpaths on chalk. 33.
- Track through Wood. 34.
- Clover. 35.
- Old pasture eaten off and sun dried.
- Old pasture from which hay has been carried. 36.
- 37.
- Potatoes. 38. Freshly cultivated and sown land.
- 39. Plough (dark strips show fresh ploughing). Mangolds (light appearance due to reflection from the very 40. 41. smooth leaves). Sown grass. 42. Permanent pasture. 43. Permanent pasture much trodden. 44. Pond. 44A. Field of grass partly cut. 45. Corn nearly ripe and much beaten down. 46. Water meadows. 47. Sheep in turnips (the light parts show where the roots have 48. been eaten off). Growing roots (the young plants do not conceal the ridge 49. and furrow). Growing wheat (green). 50. Roots. 51. Beans cut and shocked. 52. Stubble (53A Corn Stacks). 53. Wheat, A-Standing, B-Cut and lying in sheaves, C-in Shocks. 54. Standing Barley. 55. Saltings. 56. Clover cut and partly raked. 57. Ploughing on chalk, the dark strips may indicate fresh 58. ploughing.

nee Survey, 1929.



which must always be borne in mind: time of day, and season. The former is the clue to the position of the sun, and therefore to the degree of reflection, and the length of shadow to be expected. The latter controls the natural appearance (and therefore the photographic image). Where the nature, or even existence, of a particular feature is in doubt, other and overlapping photographs of the same area will help, not only stereoscopically, but because of the different point of view. Paths or streams in forest country are most visible, for example, where they run to or from the centre of the photograph.

98. Limitation by Scale

On a photograph taken at a low altitude, or with a long focal length, most objects are visible. The average scale may be taken at roughly 3 inches to the mile, and at this scale 1 foot is represented by about 1/2,000 of an inch. It is obviously impossible on such a photograph to see the actual lines of a railway, or a telegraph pole.

99. Indications of Hills

As before stated, single verticals afford no direct evidence They do, however, afford many clues to it. Thus of hills. roads and railways are graded. If a road or railway lies in a cutting it is crossing a spur, or running up and down a convex slope. If on an embankment it will be running across a stream line, or up and down a concave slope. On a sharp hill side steep banks show the top or bottom of fields, and follow the general line of contour. Sheep or cattle tracks take an easy graded line up and down hills. In vine country (Central and Southern Europe, Palestine, etc.) walls between fields follow the contour more or less, whilst in tropical Asia paddy fields (always arranged for irrigation) also follow the contour. Lines of plough are not a reliable guide because they allow of drainage in one or other direction. Shadow may show up sharp slopes, and may give some grasp of tactical feature, but is of more value in estimating the size of banks, cuttings, hedges, etc. To estimate heights in this way it is necessary to have a rough idea of the heights of the cottages and trees in that particular neighbourhood, or of the width of road or permanent way upon which the shadow is cast. The most certain clue, however, is that afforded by the rivers, streams or ponds.

100. Mosaics

Mosaics will rarely be available on service. They are difficult to make, and, in hilly country, unreliable when made. Even in flat country they should not be relied upon for distance or bearing. It is advisable to draw the map grid on the mosaic before use. The method of compiling a strip mosaic is described in Appendix IV.

101. Stereoscopic Pairs

Chapter XIII explains the use of small pocket stereoscopes. Since an overlap of 50 per cent. between successive prints is always allowed for, it is possible to examine the whole of the ground stereoscopically, and it is only in this way that the full value of the photographs can be obtained. Generally speaking, the effect of height is so exaggerated that the vertical scale is two or three times the horizontal (the further apart the two points of exposure are in the air, the more is the height scale exaggerated). Before estimating heights, then, a rough figure for the heights of hill tops, and for the bottoms of valleys should be obtained from the map. Intermediate heights can then be estimated and the size and importance of obstacles gauged. The ordinary rules of lighting, texture and reflection apply in stereoscopic as in single print examination, but it is far easier to identify the actual features of the ground. or the nature of any artificial work, stereoscopically than otherwise.

102. Negative Marks

These occur sometimes and must not be confused with details of the ground. They are usually scratches or stains on the negative. If any doubt arises compare the photograph with another which covers the same area.

CHAPTER XIII

USE OF A SIMPLE STEREOSCOPE

103. Description

The most usual type of pocket stereoscope likely to be issued for general military purposes will consist simply of a pair of prisms or half lenses, mounted in a suitable frame. The method of use is, however, independent of the particular type of stereoscope, provided the latter has been designed, or is suitable, for the size of prints which it is required to examine.

104. The Examination of Plate XXIV

Plate XXIV shows a pair of verticals, taken with the usual overlap and mounted in their correct relative positions.





[To face page 92.

PLATE XXV.





CORRECT SETTING. Notice the plateau formation with cliff road running up the near side.





REVERSED SETTING. Notice that the "plateau" now appears as a steep-sided depression. It is the overlap portion only which gives stereoscopic effect. Place the plate so that the eyes are parallel to the line PQ which joins the centres of the photographs. Hold the stereoscope close to the eyes and about 10 inches vertically above the plate. The nose should be directly over the centre of the line PQ. If the stereoscopic image is not obtained at once move the head slightly nearer to, or further from the plate, keeping the eyes parallel to the line PQ.

105. Difficulties of Stereoscopic Vision

Stereoscopic vision is not possible to all people. If the two eyes are unequal in power, or if they are not truly set, there is sure to be difficulty, and the attempt to see stereoscopically must be given up. On the other hand, spectacles or glasses are usually designed to remedy these faults. The glasses suitable for reading will normally be suitable for stereoscopic examination.

Most people can see stereoscopically either with or without glasses and find their main difficulty in lack of practice and self-confidence.

106. Setting Loose Prints

For normal stereoscopic work in peace, photographs are cut so as to leave only the overlap portion and mounted on cards in the proper position. It is not possible or advisable to cut and mount photographs on service. Each photograph includes valuable information throughout its whole area and should not be spoilt for the sake of the stereoscopic value of the overlap. It follows, however, that each observer must set or place the pair of photographs for himself, and must then find the correct height above them at which to use the stereoscope. In setting the photographs the following points must be remembered :---

i. They must be set in the order in which they were taken. This is not difficult, because it implies only that overlap must be next to overlap. Plate XXV shows the reversing effect of a wrong sequence.

ii. The light must be in the correct position relative to the shadows on the photographs (Chapter XII, Sec. 92).

iii. The eyes must be parallel to the line joining the centres of the photographs.

107. The Distance between Prints and the Height of the Stereoscope above them

The photographs must first be placed on the table, the overlaps adjacent and the detail approximately in the same orientation. The pilot may have changed direction between exposures and similar orientation of detail does not necessarily imply that the edges of the photograph are parallel.

The further apart the prints are set, the higher must the stereoscope be held in order to obtain the required effect.

The photographs may be fixed by single pins through their centres as soon as their distance apart has been regulated to suit the convenience of the observer.

108. Rotation of the Photographs about their Centres

The final setting of the photographs is obtained by rotating them slowly in opposed directions about their pin pivots until the clearest stereoscopic effect is obtained.

109. Improvised Stereoscopes

For the detection of small differences in relief within a very restricted area, such as may frequently be required in the examination of enemy field works, a suitable stereoscope may be improvised from a pair of ordinary magnifying glasses.

Each magnifying glass is placed by trial at a suitable distance to give a sharp magnified image of the photograph. The separation of the two glasses is then arranged so that the eyes are over the inner marginal portions of the lenses.

Left and right prints are chosen in the manner indicated above, but for the present purpose of examination of a very limited area no other precautions are necessary in the setting of the prints. In order to obtain easy fusion of the two photographs, the separation of the prints may be varied, or else the magnifying glasses themselves may be moved about slightly.

The magnifying glasses may be held one in each hand or, for more protracted examination, they may be supported in an improvised stand such as is illustrated in Plate XXVI. In order to prevent the prints from actually overlapping, the required portions may be cut out, or else a slit may be made in the table or box on which they are supported, the inner edges of the prints being passed down through the slit.





PART III-FIELD SKETCHING

CHAPTER XIV

PRINCIPLES OF FIELD SKETCHING

110. A Military Sketch

A sketch differs in character from a map only in so far as speed in execution is the first consideration, and accuracy of outline the second. It may not be possible in the time available to make the sketch either complete or accurate in every detail. The information recorded must, however, be reliable. Speed and reliability are, in fact, the essence of military sketching; but it is only by practice and by following certain principles that they can be acquired. Without proper training, without understanding the value of the "control," and without the neat "finish" which comes from practice, few helpful or readable sketches will be produced. In the first instance, then, instruction must aim at accuracy, proper sequence and neatness. When these have been acquired the pace may be increased.

111. Object

- 1. The object of a military sketch is :-
 - i. to add to the available maps any additional information required; or
 - ii. to illustrate a report or reconnaissance.

2. A sketch must be :--

- i. completed in time to be of use ;
- ii. clear and legible ;
- iii. relevant to the object for which it is undertaken ;
- iv. as accurate and complete in detail as circumstances permit.

112. Principles and Methods

- 1. The principles are as follows :--
 - i. A control of accurately fixed, heighted and correctly plotted points is the essential preliminary.
 - ii. Detail may then be sketched in and checked, wherever possible, from the control.
 - iii. Traverses start and finish upon accurately fixed points.

2. In carrying out these principles the following methods apply :--

- i. Points are fixed by intersection (bearing from two known points), bearing and distance (from one known point) or resection (bearings to three known points, or to two known points if the sketch is properly oriented).
- ii. No position is accepted without a check, wherever a check is possible.

These principles and methods apply to all forms of sketching.

113. Choice of Scale

The scale must depend on the object in view, the amount of detail required (Chapter III, Sec. 16) and the time available. Thus for sketches of platoon or company positions a scale of six inches or more to the mile may be used. More extended positions for battalion or brigade should be sketched at two or three inches to the mile, and for large areas or long distances the one inch or half inch scales will be found the most useful.

114. The Framework

The points of the framework, or "ruling points," should be features well defined on the ground, such as hill tops, tall or isolated trees, church spires, chimneys or windmills, which can be seen from at least two other points and from as much of the area to be sketched as possible. As many will be fixed as time permits and the required accuracy demands. The more that are fixed the less will be the chance of error in sketching in the intermediate detail.

When maps of the area to be sketched are available the relative positions of suitable points may be transferred from the map to the sketch, either at the same or at an enlarged scale (Chapter IX).

In determining where to plot the first ruling point on the sketch the general shape of the area must be considered and the position so chosen as to bring the whole of the area on to the paper.

115. Methods

The following are the methods described for field sketching :---

- i. Plane Table sketching. Chapter XV.
- ii. Compass sketching. Chapter XVI. iii. Eye and Memory Sketching. Chapter XVII.
- iv. Sketching from Aeroplane Photographs. Chapter XVIII.

i, ii and iii are in order of accuracy, and iv, of a quite different nature, should be regarded more as a method of

filling in difficult detail than as a method of making a complete sketch.

The method employed will depend on the military situation, the object in view, the country and the time available. As a rule more than one will be used, the least important points being fixed by the least accurate methods.

As much detail as possible should be sketched in at the same time as the ruling points are being fixed. If this is not done much time will be wasted in going over the ground a second time.

116. Measurement of Distances

Directions or angles are measured graphically with the sight rule (Chapter XIX) or read by compass and then plotted (Chapter X). The intersection of rays fixes the positions of points, but if only one ray (or direction) is available then a distance must be measured or estimated.

Measurement of distance is done in one or other of the following ways :---

Usual errors.

G

i.	Chain, tape or	rope of k	nown lengt	th 1	unit in 500 units (a).
ii.	Range Finder	(Infantry	pattern)		unit in 250 units (b).
iii. iv.	Cyclometer Pacing			1	unit in 100 units (c). unit in 50 units.

NOTES .--

 (a) Depends upon the type used—may be very accurate, but linen tapes or ropes sometimes give much more error than here described,
(b) Depends on the square of the distance—accurate for short dis-

tances, inaccurate for long distances.

(c) Inaccurate for short distances.

Of these four methods of measurement pacing is the most useful for sketching detail, although i, ii or iii may be used with advantage on occasion. For example, in the rapid sketch of a piquet position the range-finder would play an important part.

It is easier to learn to pace yards than to prepare and use a special scale of paces which are longer or shorter than yards. Pacing yards should be practised on level ground. The impulse is to pace short going uphill or across rough ground, and to pace long on gentle downhill slopes. In counting paces some system must be adopted for keeping a check on the number of hundreds paced. This may be done by ticking off each hundred on a slip of paper or turning up a finger. Over a long distance large numbers may be avoided by counting only every fourth pace, say every second pace with the left foot, and multiplying the total by four.

117. Finish and Conventional Signs

During the course of sketching work must be kept clean, clear and legible. Keep the pencil sharp, use clean indiarubber and write all names in final form wherever possible. The following rules must be observed :--

i. Use the conventional signs of Plate V, Chapter IV.

- ii. Add the correct grid squares and numbers.
- iii. Add written description if necessary, but in simple clear terms, and do not overcrowd the sketch.
- iv. Write important names in plain block capitals-

e.g. FARNBOROUGH,

less important names in small printing-

e.g. Nether Wallop.

Avoid fancy writing and write names to the right of the position or place-

e.g. Charthill Manor.

- v. Sketches not made in the immediate presence of the enemy should be oriented so that the top is the north. This is the rule with all maps and sketches will be used with the map. Minor tactical sketches made during operations should show the direction of the enemy at the top.
- vi. In large-scale tactical sketches avoid the following common errors :---
 - (a) Cuttings and embankments out of proportion.
 - (b) Cross strokes, as in cuttings, embankments, railways (sleepers) and in cross-shading houses, irregular, and not parallel.
 - (c) Roads not true to scale, not bordered by parallel lines, and untidy at cross-roads or junctions.
 - (d) Bad numbering of contours. These should be clearly marked so as not to interfere with other important detail.
- vii. In finishing, add :--
 - (a) Title (including reference to report or purpose).(b) North points.

 - (c) Scale.
 - (d) Vertical interval employed.
 - (e) Date, time and weather conditions.
 - (f) Signature and rank.

CHAPTER XV

PLANE TABLE SKETCHING

118. Principles

It may sometimes be necessary to make a sketch of an area which has already been triangulated, and for which a list of the co-ordinates of the points or apices of the triangulation is available. In such a case the points will be plotted in their correct positions at the chosen scale, and sketching will be limited to filling in the detail and contours on that plotted skeleton. More often, however, the skeleton of control points must be fixed at the time. Plane Tabling is the most accurate method of fixing control points and has the advantage of requiring only one measured distance or base.

In all methods of sketching, the position of an unknown point may be fixed either by the intersection of rays (or directions) from two (or more) previously fixed points, or by the ray (or direction) and distance from one previously fixed point. The particular advantage of plane tabling is that, once the plane table has been set, directions are measured easily and accurately by aligning the sight rule on each point in turn. A skilled plane tabler fixes nearly everything by the intersection of rays and rarely has to measure distance.

119. Instruments Required

The Plane Table, Sight Rule (or alidade), Trough Compass and Clinometer are the chief instruments employed. The description and use of these instruments are dealt with in Chapter XIX, which should be studied before proceeding with this Chapter. Minor stores and instruments required include boxwood scales, pencils, drawing paper, drawing pins, indiarubber, a knife and a piece of emery paper (a file or a match box will do).

120. Setting the Plane Table

Setting the plane table means orienting it so that every line on the sketch is parallel to the line it represents on the ground. There are two methods of setting :---

i. By sight rule set on a distant known point.—Lay the sight rule along the line joining the two known points, of which one is the known position of the plane table, and the other the known position of the distant point. Rotate the board till the sights of the rule are on the distant point. The board is then set, because the line on the sketch has been brought parallel to the line it represents on the ground.

It is not easy to lay the sight rule accurately along a short line, and yet it is most important to safeguard the accuracy of setting. Every line, to be used subsequently for setting, should be prolonged by ticks made at the ends of the sight rule in the margins of the sketch.

ii. By compass.—At any time when the board is set, place the trough compass on it, and move the compass box till the needle reads zero. Then draw a line (or rectangle) in pencil round the compass box. To reset, place the compass accurately in this rectangle, and rotate the board till the needle reads zero. Compasses are subject to various errors as explained in Chapter X, Sec. 68, and for this reason setting by compass is never absolutely reliable. Always set on a distant point for preference.

121. Procedure. Choice of the Base

The first step is to choose a base. The two ends must be intervisible and the ground between fairly flat. The position of the base should be such that ruling points can be fixed from it by intersection. The ends of the base should be conspicuous trees or posts, but if good natural objects are not available, banderoles, flags or poles should be used. Paper or linen firmly secured to bushes or hedge corners will serve.

The base is measured by one or other of the methods given in Chapter XIV, Sec. 116, plotted on the plane table at the adopted scale, and put in such a position that the whole sketch will come conveniently on the plane table.

122. Fixing Ruling Points

The next step is to fix by intersection a number of ruling points covering the area. Ruling points must be conspicuous and easily recognized. Houses, trees, rocks, chimneys, flagstaffs, windmills and telegraph poles are good. Vague and ill-defined points, such as corners of woods, or junctions of hedges, are not good ruling points and should not be used as such if better defined points exist.

Ruling points are intersected on the plane table as follows :— Set up the table at one end of the base A. With the sight rule set the board on the further end of the base B. Pivot the sight rule round the plotted position of A (on the board a) and align the sight on a chosen ruling point C (on the board c). Draw a line ac on the board along the sight rule, which will represent the direction of AC in nature. Similarly draw rays to any other ruling points visible from A such as D, Y and Z (Fig. 37). Proceed to the other end of the base (B) and set the board on A. Pivot the sight rule about the point b on the board (representing B in nature), till the sights are on C. Draw the ray bc. The point where ac and bc intersect is the position of c on the board corresponding to C in nature. In a similar manner draw rays to D and Y, thus fixing their



position, and to E, F and G, which are also to be fixed but were not visible from A. C is next visited, the board set on A or B, and rays drawn to Y, giving a check on its position as previously fixed, and to E and G, fixing both these points.

Following the same procedure the framework of ruling points can be expanded to cover the whole area. The more nearly that intersecting lines meet at right angles, the more



accurately is the point of intersection fixed. An ideal intersection is seldom possible, but none should be less than 30° in the case of ruling points. With a broad angle of intersection a small error in the direction of either ray produces but little error in the position of the point, whereas, with a narrow intersection, the same small error will have a much greater effect (Fig. 38).

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123. Using Enlargement as Framework

Should a reliable map of the country exist, it is quicker to make an enlargement (Chapter IX, Sec. 59) for use as the framework, than to fix ruling points as explained above. Maps of foreign countries are, however, frequently unreliable and common sense must decide whether they can safely be used for this purpose.

124. Fixing Detail

A suitable framework once obtained, the next step is to hang the detail on to this framework. The detail can be put in :—

- i. By eye from the fixed points.
- ii. By a direction and paced measurement from a fixed point.

iii. By intersection.For example see Fig. 39.



FIG. 39:

Let A, B and D be fixed points. Starting at A the hedges AB and AD can be drawn in by eye. Rays will be drawn to the junctions of hedges at (1) and (2).

Moving to D, rays are drawn to (2) and (3), and down the road to (1), thus fixing the position of (1), the hedge (1)-(3),

and the end of the hedge at (2). At (1) the board is set on A and checked on D. A ray to (5) is drawn and the distance (1)-(4) is paced, the farm at this point being put in by eye, and a ray drawn to (8). Pacing on to (5) the board is set on the ray (5)–(1), and rays drawn to (6), and along the road towards (7). The distance (5)-(6) is paced, and (6) plotted. Move to B by road, pacing the distance (7)-B. At B, set the board on A, and draw the ray B-(7)-(6). Plot the distance B-(7). This fixes the hedge (2)-(8)-7 and the road (5)-(7), the curves being put in by eye, and gives a check on the plotted position of (6). For the sake of explanation it has been assumed that the ground is difficult and sight restricted. In open country the whole of the detail might well be inserted by intersection from A, B and D. Normal country is not generally so well supplied with ruling points, and it is often necessary to set up at an unknown point and to find its position before beginning to put in detail. Position is found by either of the following methods :--

i. Resection.

ii. Lining up and cutting in.

125. Resection

Resection is the term used for the process of fixing a position from previously fixed points without actually visiting them.

There are two ways in which it can be done—

- i. From three fixed points.
- ii. From two fixed points, setting with the trough compass.

The second method is less accurate than the first, and should not be used when three fixed points can be identified.

126. Resection from three Fixed Points

Set up the plane table at or near the point to be fixed so that three previously fixed points can be seen. Set the table by the trough compass and, from the three fixed points, draw back rays.* If the three rays pass through a point, that point is the required position. If they do not, they will form a triangle, called the "triangle of error." The true position is now determined by the following rules:—

i. If the triangle of error is inside the triangle formed by the three fixed points, the required position is inside the triangle of error; and if outside, the position is outside the triangle of error.

• A " back ray " is one drawn from a distant point towards the position of the plane table. The latter being unknown, the sight rule is pivoted round the distant point until the sights are on it, and the " back ray " is then drawn towards the observer. ii. In the latter case the position will be such that it is either to the left of all the rays when facing the fixed points, or to the right of them all. Of the six sectors formed by the rays, there are only two in which this condition can be fulfilled.

iii. Finally the exact position is determined by the condition that its distances from the rays must be proportional to the lengths of the rays, *i.e.* the position on the sketch must be nearest to that side of the triangle of error formed by the shortest ray, and farthest from that formed by the longest ray.

In Fig. 40, for instance :--



FIG. 40.

By condition i the point must be outside the triangle of error.

By condition ii the point must be in sector 6 or in sector 3.

By condition iii the point must be in sector 6, since the distances from it to the rays must be proportional to the lengths of the rays, and by estimation it will be where shown.

Having thus determined the position, set the board on the most distant of the points used; clamp, and test on the other two points. If there is still a triangle of error (which, however, should be much smaller) go through the process again.

Resection is most accurate when the plane table is set up inside the triangle formed by the three points. If outside the triangle, the best results are obtained when the angle between the extreme rays is large : 60° is rarely more than fair, whilst 180° is usually good.

Accuracy of position is ensured by two points being near, whilst accuracy of setting is ensured by aligning on a distant point. Generally speaking, fix from near points and set from distant points.

The method of resection fails when the circle which passes through the three fixed points also passes through the position to be fixed. This is known as the danger circle and, when the three points and the required position lie on this circle, the three rays will pass through a common point, whatever be the setting of the sketch, and no triangle of error can be obtained. When resecting, therefore, care should be taken to see that the position is not on or near the danger circle.

If there are more than three points from which a resection can be obtained, those most accurately fixed should be used, provided that they are well situated, and do not form a "danger circle."

Before accepting as final a resection from three points a check ray should be drawn from a fourth point.

127. Resection from two Fixed Points, Setting with the Trough Compass

Set the board by the trough compass and draw back rays from the two fixed points. The intersection of these two rays gives the required position. It must be remembered that accuracy is dependent on the setting, and therefore on the reliability of the compass. This method is justifiable where the resecting rays are short, or where extreme accuracy is not of importance.

128. " Lining up " and " Lining in "

These two terms are used for the process of setting up the plane table on a line which has already been surveyed and drawn. The simplest case is that of setting up at a point to which a ray has been drawn, and orienting on the station from which that ray emanates. In many cases, however, a line is surveyed and drawn without reference to a particular point. For example, the straight line of a long fence, of a telegraph line or of a road or railway may have been fixed and plotted. At any point on such a line the board may be set up, and the process of "lining up" is that of setting, by placing the sight rule along the line in question, and revolving the board until the sight rule is pointing in the proper direction. is a useful application of this process in setting the table at a point in line with two previously fixed points. Supposing these two points to lie on the same side of the observer, it is easy to set up so that the two points are in line (Fig. 30). The process of "lining in" between two previously fixed points is slightly more complicated, and has already been described in Sec. 54, ii (setting a map). For sketching, the procedure is elaborated by using the plane table and

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sight rule, and is carried out as follows. Set up the plane table as near as can be judged on the line between the two fixed points A and B, Fig. 41, which are plotted as a and b. Place the sight rule along ba, and rotate the table till the rule



FIG. 41.

points to A. Clamp the table and reverse the sight rule along *ab*. If it now points to B, the table is on the line AB and is set; if B appears to the right (left) of the sight rule, the table must be moved to the right (left) and the process repeated.

129. Cutting in

Having lined up, or lined in, the next step is to cut in or to establish the point on the known line at which the observer stands. The board is "set" on the line as described above, and the sight rule directed to some fixed point lying preferably at right angles to the known line. A back ray from this



point determines the position. In Fig. 42 the plane table is *lined up* (or *in*) on the line AB, and on the table the back ray cx cuts ab in x, giving the position required.

A check back ray from some other fixed point (such as d, Fig. 42) should be obtained whenever possible.

130. Traversing

Some types of country are so enclosed that it may be impossible either to fix sufficient ruling points, or to put in the detail by the methods described above. In such cases traverses must be employed. Traversing is slow and peculiarly liable to the accumulation of error, because every error of measuring distance, or of setting, affects the whole of the work which follows.

Traversing is best explained by an example. Suppose it is required to sketch the course of a stream and the detail adjoining it (Fig. 43). Let A, B, C, D, E and F be recognizable points near the stream, each of which is visible from the preceding and following points. Choose a point a on the sketch to represent A in nature, and draw a ray to represent the direction AB. Pace (or otherwise measure) the distance AB, and mark a point b (on ab) such that ab represents the paced distance AB at the required scale. At B set the sketch on A. This method of setting the sketch is known



as "setting by the back ray." With the table clamped, pivot the sight rule about b until the sights are directed upon C, and draw the ray bc. Pace the distance BC and plot c. Proceeding in this manner the skeleton of a traverse is obtained, each of the portions AB, BC, etc., being called "legs."

Detail may be inserted on the sketch by eye, by intersections or by "offsets." An offset is the perpendicular distance of a point from the leg of a traverse and may be paced or estimated. The distances along a leg at which offsets are measured and other data for plotting the offsets should be noted on a separate piece of paper during the measurement of the leg; the offsets can then be plotted on reaching the end of the leg. The offsets necessary to plot the position of the stream, in Fig. 43, are shown in dotted lines and typical intersections are also indicated.

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131. Setting the Plane Table at Traverse Stations

There are disadvantages in setting by the back ray. Supposing that, at C, the sketch was incorrectly set on the last station. This one bad setting will have a cumulative effect on the subsequent work even if no further mistakes are made (Fig. 44). Setting by compass has the advantage that



Pecked line shews effect of a single error in setting by back ray at C.

FIG. 44.

if a mistake in orientation is made at one point, and the subsequent work is good, the effect on the traverse as a whole will be less than if the board had been set by the back ray (Fig. 45).

Whether setting is by compass or back ray, the orientation should always be checked when it is possible to see some distant and previously fixed point. The further away such



Pecked line shews effect of a single error in setting by compass at C.

FIG. 45.

a point is the better. The best check of all is a resection from 3 known points, and the opportunity of securing it must never be missed.

132. Adjustment of Traverses

Whenever possible a traverse should begin and end on fixed points, or on points that can be fixed subsequently. The traverse can then be adjusted for scale errors between them. The adjustment should be done on tracing paper by



PLATE XXVII



Primais at the Geographical Section General Statt War Differ

enlargement or reduction (Chapter IX, Sec. 59) and then pricked through on to the sketch.

133. Description of a Plane Table Sketch

In practice, ruling points and detail are fixed at the same time, the various steps described in the preceding sections being carried out concurrently. In order to give the student a clear mental picture, the initial stages of the making of an accurate military sketch will be described. On service the object in view or the time available may not allow of similar accuracy. In that case the number of resected points would be reduced, fewer distances would be paced and more of the detail would be sketched by eye.

i. Plate XXVII. The area to be sketched extends from Bexley Point (515760) south through YAVERLAND (475550). The scale chosen is 1/20,000. The first step is to obtain a good view of the ground, and the obvious place from which to do so is the hill near BEMERIDEE FORT. From there it would be decided to measure a base on the marshes to the north, and to extend a graphic triangulation from that base up to the FORT, and thence to the low ground to the south. This proposed framework is shown in red on Plate XXVII.

ii. The base would be well placed at A–B, and its length would be measured by careful pacing (or better with wheel or tape). No natural objects mark the ends and some form of visible signal would be erected at each end, to be used later for resection.

iii. Plane-tabling would begin as follows :---

Set up over one end of the base (A), choosing a position and orientation for the base A-B such that the whole area will come on the paper. Draw in the ray AB and plot the base on it in accordance with the chosen scale.

iv. Test the orientation again on B. Draw the northpoint in with the trough-compass and draw rays to the ruling points C, G, F and D, writing the descriptions of these points along short lengths of the rays on the edge of the paper. Draw rays to other prominent points, such as the Pumping Station, Monument (660541), the fence corner by Weirs (541750) and so on. Draw a ray to the footpath near A, pace along this ray to the footpath and plot. Move to B.

v. Set up at B and orient on A. Intersect C, D and F and draw a ray to the ruling point E. Draw a ray parallel to, and up and down the stream, and intersect the fence corner near Weirs. This latter point is now fixed. Sketch in the stream between this corner and B. Intersect any points that have been taken from A. The Pumping Station will now be fixed and may be sketched in together with the footpath passing A. Take rays to other useful points such as the two foot-bridges to the south-west.

vi. Pace down the stream (south-west) to the fence and plot. Sketch in the detail.

vii. Set up at C, orient on A and test on B. Intersect E and any other prominent points. Take a ray up the hedge to the north, and sketch it in. Ray up the railway to the north-east, move up to the fence junction, and sketch in. The plane-table sheet will now look something like Plate XXVIII.

viii. Return to C. Ray and pace down the railway towards E, sketching in the detail on the way. When the river leaves the railway near E, move to E, set up, orient on C and check on A or B. Take rays, as before, to other ruling points and to prominent points of detail. Take rays to detail near E and sketch this in by eye. Ray down the footpath to the south-east. Then move to the foot-bridge on this path, to which a ray has already been taken from B. Set up and cut in from E; check on D or F. Intersect any useful points, and sketch in detail round about.

ix. Move to foot-bridge at junction of tracks and stream. Again cut in from E. Take rays to other points on the stream, sketch in the stream and the footpaths, and take a ray to the near corner of Centurion's Copse. Then move along the north edge of Centurion's Copse, resecting at the two prominent corners, and sketching the minor bends by eye. Make for the higher ground and set up at the hedgecorner south of WOLVERTON. Resect from A, B and D, and check on F. Ray on to the corners of the east side of Centurion's Copse. Sketch in neighbouring fences and move to D.

x. Set up at D and intersect corners on east side of Centurion's Copse, thus obtaining and sketching in the shape of the wood. Intersect other useful points, and ray and pace down the road to the Longlands Chalk Pit. Resect just above the Chalk Pit, and sketch in the road detail below by eye. Climb the hill to F, and from there intersect G, and the Monument, taking rays to forward points which will be visible from G. Take rays to the corners of the south edge of Centurion's Copse, and a ray to the junction of the hedge for. Sketch in the detail of Bembridge Fort.

xi. Work down the road towards Old Marl Pits, intersecting the corners of Centurion's Copse previously taken from F. Sketch in the road on arrival at the Old Marl Pits, and complete the detail of Centurion's Copse and the track to the west of it by occupying stations 17 and 18 (Plate XXIX).





xii. Then work up to G and continue. Plate XXIX shows the detail already sketched at this stage, the occupied stations being numbered in their order of visitation.

134. Relief (Principles)

No military sketch is complete without contours or form lines. In Plane Table sketching the relief is shown by form lines, sketched by eye, but controlled by a number of heights fixed with the clinometer or aneroid barometer.

135. The Clinometer

Either of the clinometers described in Chapter XIX may be used, but the Indian Clinometer gives the best results. One of the scales of the Indian clinometer is graduated to read the tangent of the slope, and this figure, multiplied by the distance in feet (yards or metres), gives the difference of height in feet (yards or metres). The difference of height added to, or subtracted from the height of the known point gives the height of the unknown. As the clinometer is usually on the plane table, the height of the latter, usually about 3 ft. 6 ins., must be taken into account. A clinometer, with the wire on the forward vane set at zero, will show what other points are at the same level, and hence how the contour or form line of that level, runs.

136. The Aneroid

For rapid work, when much accuracy is not required, an aneroid barometer is often used. This instrument has the advantage that it gives a definite answer without calculation, but the disadvantage that a point has to be visited before its height can be obtained. The aneroid is therefore seldom used with a plane table. A description of this instrument and how to use it is given in Chapter XIX.

137 Procedure in obtaining Height Control

The height of one point in the area to be sketched must be known or assumed and is called the "datum." If the datum is assumed the resulting form lines will be relatively correct, but will not be so in relation to Mean Sea Level. A note must be made of the assumed datum height, so that the heights given for the form lines may be corrected, if it is possible to improve the datum height later on.

The height (or vertical) control consists of the heights of all ruling or other fixed points, and of such additional points in the valleys and on the spurs as may help in the actual sketching of the form lines. The greater the number of heights fixed, the easier does the sketching of the form lines become. The fixing of these heights and the actual sketching of the form lines is, in practice, carried out concurrently with the detail sketching.

During the sketching of the detail the tangent of the angle of elevation, or depression, should be written against any ray to a point whose position is afterwards to be fixed, so that the height can be worked out as soon as the position is fixed.

Generally speaking, the height of a point should be the mean of two results. In the case of a height fixed by one long and one short ray, the value from the latter should be accepted. The longer the ray, the greater the chance of error.

When there is not time to fix many heights, they may be limited to the tops of hills and the bottoms of valleys. The number of form lines between can then be calculated and their positions sketched in by eye in accordance with the type of slope.

138. The Sketching of Form Lines

This is best explained by an example :---

Example.—Plate XXX gives the outline of a sketch showing points of known height, and containing information as to the slopes and relief. The problem is to fill in, on this framework, form-lines at 20 ft, V.I.

i. Consider the main watercourse and, guided by the three heights 610 near its source and 485 and 466 further down, interpolate the probable crossing points of form-lines by trial and error (Plate XXX). The slopes of watercourses are generally uniform except near their source where they may be concave, and thus form-lines, normally close together near the source, will gradually separate as the watercourse descends.

ii. Next follow the main ridge downwards and mark on it the 620 form-line just above the point 619. The 600 formline must occur between points 619 and 591. The drop from 619 to 591 is 28 feet, whilst that to the 600 form-line is only 19 feet. The form-line will lie then at 19/28ths (or, roughly, 2/3rds) of the distance, below 619, and the point at which it crosses the spur can be marked in by eye.

iii. The 600 form-line will occur again between points 591 and 613, but as 613 is marked as a knoll and therefore probably has steep sides in the region of the knoll itself, it will suffice to mark the 600 form-line as a small ring round this point. Let c be the point where this ring form-line cuts the next ridge line below 613.

iv. Between c and point 546 the slope is uniform and is crossed by two form-lines, 580 and 560, at points e and d, Point d is obviously just below point 565 and e will occur half-way between c and d.



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- vii. In making an intersection it is not necessary to draw the whole of the second and subsequent rays. About half an inch across the point of intersection is ample.
- viii. Keep the sketch as neat and clean as possible. Neatness tends to accuracy. If the plane-table top is carried on the back, in its cover, make sure that the sketch is turned outwards.
- ix. When aligning the sight-rule upon a distant or indistinct object, keep both eyes open. The point will be seen more clearly than with one eye closed.
- x. There is a natural tendency to exaggerate curves, when viewing the curved line in the direction of its length. A road XY, Fig. 46 (a), when sketched

x x x

FIG. 46 (a). FIG. 46 (b).

from X, is often represented on a sketch as shown in Fig. 46 (b). The correct procedure is to estimate how far the road departs from the straight.

xi. It is advisable to "prick" every point of the graphic triangulation, and every resection. A round-headed steel pin, or a needle with a piece of sealing-wax on the blunt end, acts well as a pricker. A pricked point is never lost.

CHAPTER XVI

PRISMATIC COMPASS SKETCHING

140. Fixing and Plotting the Framework

The process of fixing the framework from the ends of a base, and of intersecting other points subsequently, is similar to that explained in Chapter XV, Sec. 122, except that the compass is used instead of the sight rule for obtaining direction. In plane tabling, directions are drawn direct on paper ; in compass sketching, bearings are read from the compass and plotted on the paper with the protractor. The description and use of both these instruments will be found in Chapter X.

The paper used for plane tabling should be plain, but for compass sketching it is convenient to use squared or ruled paper, the vertical lines of which may be used to represent
magnetic meridians. If no ruled paper is available, parallel lines about two inches apart should be plotted first of all. Bearings can be plotted direct from these lines.

141. Resection

Once the framework is established, the position of any further point can be found by resection with the compass





from two known objects. The bearing of a third point should be used, whenever possible, as a check.

 and D are three ruling points, already fixed on the sketch, whose compass bearings from A are, respectively, 340° , 60° and 120° . Since direct and reverse bearings differ by 180°, the reverse bearing can be found by adding 180° if the original bearing lies between 0° and 180°, or by subtracting 180° if the original lies between 180° and 360°.

Thus the bearing from B to A=340°-180°

 $=160^{\circ}$ C to A = 60°+180° =240° D to A = 120°+180° =300°

Lay these bearings off on the sketch with a protractor, and the point of intersection will give the position of A. Should the three lines give a triangle of error, instead of an intersection, bearings and plotting should be checked. If a triangle of error still results, the correct position can be found as described in Chapter XV, Sec. **126**.

142. Traversing

A traverse is a sequence of measured lengths, or legs, each of which lies on a measured direction or bearing. As in plane table traversing, the legs are generally measured by pacing, although a range finder, wheel, or tape gives more accurate results. Bearings, taken with the compass, are plotted as described in Sec. 140. Plotting may be done with advantage in the field, for, with the ground actually under observation, it is easier to ensure that no important feature is omitted, and that no mistakes are made. The tactical situation, or lack of time, may make it necessary, however, to record bearings and measurements in a notebook, and to postpone plotting for a subsequent occasion. Plate XXXII shows the "booking" of part of a traverse and the traverse plotted from it. It is wise to work from the bottom of the page upwards, *i.e.* in the direction of movement. In column 1 are shown the numbers of the traverse stations and the forward bearings from each station. In column 2 are given the paced distances from the last (back) station to points of detail on the traverse. The top figure, between two stations, is the total distance between those stations and should be written sideways, to distinguish it from distances at which offsets are taken. In columns 3 and 4 the detail along the traverse is shown diagrammatically, the dividing line between the columns representing the actual line of the traverse from station to station. Conventional signs are used, as far as possible, and distances, or "offsets" (measured at right angles to the traverse line) are recorded. The bearings of roads, rivers, railways, hedges, etc., which cross or leave the traverse





line are shown. Bearings taken from traverse stations to distant features are shown by dotted rays, along which are noted names, bearings and slopes.

Heights taken with an aneroid or slopes measured with the clinometer (or Abney level) are entered in column 5.

143. Relief and Form Lines

If time presses, heights and form lines may be based entirely upon readings from an aneroid barometer. The use of this instrument is described in Chapter XIX, Sec. 170. Unfortunately an aneroid barometer, depending as it does upon atmospheric pressure, is continually changing its datum. Wherever it is possible to do so, a start should be made at one known height (e.g. a spot height given on some small scale map) and the aneroid should be checked on another towards, or at the end of the traverse. The difference of aneroid datum between first and last reading can then be adjusted. Chapter XIX must be studied before any extended use is made of the aneroid barometer. Barometer readings may be amplified by the measurement of slopes with a clinometer.

The insertion of form lines is often simplified by the use of a scale of Horizontal Equivalents. Once the vertical interval and the scale of the sketch have been decided upon, the horizontal equivalents, for slopes from 1° up to 10° or 15° (depending on the country), can be plotted in the form of a scale (Plate VII). A piece of carboard or an edge of the protractor may be used for the purpose.

Generally speaking, a clinometer will be read at the level of the eye, and the instrument should be directed upon an object (say the top of a fence) at about the same height as the eye.

It is essential in sketching form lines to follow a definite and clear sequence which is the same whatever instruments may be used. Chapter XV, Secs. 137 and 138, and Plates XXX and XXXI, should be studied and followed, for compass sketching as well as for plane tabling.

144. A Comparison of Plane Table and Compass Sketching

1. The plane table is a conspicuous object, and most of the plotting must be finished in the field. The prismatic compass is inconspicuous and may be used with a notebook, to acquire data for subsequent plotting.

2. After a little practice plane tabling is quicker and more accurate than compass sketching, but without practice the reverse will be the case.

3. The prismatic compass is more suitable for traversing than the plane table, but it is much less suitable for sketching an area in open country.

CHAPTER XVII

EYE AND MEMORY SKETCHING

145. General

For any large area or wherever accuracy is of importance, sketches should be made with the proper instruments, and in the manner described in the preceding chapters. There may arise occasions, however, when instruments are not forthcoming, and when the immediate presence of the enemy makes it imperative to give a general idea of the tactical features. Eye or memory sketching must then be resorted to. It must not be thought that the rough and ready methods employed in eye and memory sketching obviate the necessity for Survey principles. The Principles of Field Sketching apply to these, as to any other forms of sketching, and the best results will be obtained by working methodically, first on the control and then upon the detail.

146. Respective Spheres of Eye and Memory Sketching

Eye sketching implies that the directions, distances, positions and slopes are recorded graphically at the time, and on the ground. It may not be possible to make a complete eye sketch in the time available, however, and in such a case the detail may be filled in from memory. In other cases the whole sketch may have to depend on memory.

147. Improvising Material for Eye Sketching

The sketch should be drawn in a pocket-book (Army Book 152 or 153 will do), or on a flat board, on which a sheet of paper can be pinned or tied. Any "straight edge" of wood or cardboard will serve the purpose of an alidade. Assuming that neither protractor nor boxwood scale is available, a scale must be improvised on a piece of cardboard, or the edge of a folded sheet of paper. This scale must be graduated by eye, or by utilizing some known measurement, such as a halfpenny, whose diameter is one inch. The quarter inch squares of Army Books 152 and 153, or the lines on ruled foolscap, which are usually one-third of an inch apart, may be used in constructing the scale, or it may be possible to employ the scale of any map, carried at the moment, for the same purpose.

148. The Procedure of Eye Sketching

The following procedure should be followed in eye sketching :---

 Ruling points will be fixed by intersection from a paced base, or by direction (with the straight edge) and estimation. When drawing rays or lining up on a distant object with the straight edge, attention should be paid to the following points :---

- (a) The notebook (or board) must be held or placed horizontally.
- (b) The eye must be well back from, but in the line of the straight edge.
- (c) The eye must always be in the same position relative to the straight edge.
- Detail will be sketched by eye, and both directions and distances will be estimated (Chapter XV, Sec. 124).
- iii. The shape of the ground will be indicated by form lines, a sufficient number of these being drawn to show relative heights, the nature of slopes (*i.e.* concave and convex), and the relative degree of slope. No exact heights can be given, and therefore no definite value can be given to the Vertical Interval.

149. Memory Sketching

It may happen on service that sketching on the ground is impossible. In such circumstances a memory sketch may form a useful complement to a report. When possible, rough notes as to directions, distances and the shape of the ground should be made during reconnaissance, but it will be found that with practice a fair representation of the ground should be memorized in the following order:—Firstly, the stream lines or drainage system; secondly, the hill features, their general distribution, shape and relative height; and, lastly, the roads, railways, woods and other points of detail of tactical importance. No attempt should be made to burden the memory with unimportant detail. When drawing the sketch it should be built up in the same order as above.

150. Time

In eye and memory sketching the question of time must always be borne in mind. The inclusion of detail of no tactical importance not only tends to obscure the important points, but wastes time and may make it impossible to complete the sketch. In eye sketching, for example, it is a waste of time to attempt to fix points of detail with an accuracy not warranted by that of the ruling points.

151. Finish

When complete the sketch should be "finished" (Chapter XIV, Sec. 117), and reference made in the heading to the method employed. Unless this is done, those for whom it is intended may place an undue reliance on its accuracy.

CHAPTER XVIII

SKETCHING FROM AIR PHOTOGRAPHS

152. A Vertical not a Plan

1. The most useful type of photograph for sketching, as for mapping, is the vertical, taken with an overlap of at least 50 per cent. Verticals should always be taken as nearly perfect in plan as possible; that is during a straight and level flight. Unfortunately perfection is not possible, and in practice the camera is always tilted very slightly in one direction or the other. The tilt will probably be less than 2 degrees if flying is undisturbed, but may reach 10 degrees on service.

2. Till .- Suppose Fig. 48 to represent a tilted vertical



Scale too small. This edge of the photo has been tilted away from the board.

Scale too large. This edge of the photo has been tilted towards the board.

FIG. 48.

of a chessboard. The effect on the squares, or grid, is to introduce differences of scale. The photograph is, in fact, a perspective view, and parallel lines of the grid will either meet at "vanishing points," or else, if themselves parallel to the horizon, become closer and closer together.

3. Differences of Height.—The rays of reflected light from the area photographed converge in a cone having its apex at the lens of the camera, as shown in Fig. 49. A glance at that figure will show that the higher a point is, the further away from the centre of the photograph will its image appear.

153. Combined Effect of Tilt and Height

The effects of tilt and height distortion are difficult to dis-

entangle to the extent necessary in accurate mapping. For sketching it is sufficient, in all but the most mountainous country, to work on perspective principles, and to eliminate extreme errors due to differences of height, by avoiding the





use, for control, of points which lie much above or below the average level.

154. Scope of Sketching from Air Photographs

Sketching from air photographs will generally take one or other of the following two forms :---

i. Amplifying detail on map or sketch.

E.g.—New buildings, roads, railways, or even whole villages or suburbs may be lacking on an out-of-date map.

Or—Thick and difficult country (say a village with many enclosures and trees) may occur in the area of a sketch and may be copied from an air photograph.

ii. Correcting or amplifying contours.

E.g.—In an enlargement from a map the number of contours may be doubled and their shape much improved.

155. Amplifying Detail with the Proportional Dividers

 If time is short, and accuracy not essential, detail may be added with the proportional dividers as follows (see Chapter XIX, Sec. 168, for description of the proportional dividers):— In Fig. 50, A and B are points already mapped, and also visible on the photograph at a and b. c, visible on the photograph, is to be added to the map. Set the proportional dividers so that when the points of one end read the distance A-B, those of the other read a-b. The difference of scale between map and photograph has now been obtained.

With the "photo end" of the dividers set to the distance a-c, set the "map end" on A and scratch (very lightly) an

· C



arc near the correct position for C. Do the same at B, using the distance B-C and intersect the former arc at C. C will then be in its correct relative position.

2. With a sufficient number of points added in this way detail may be drawn in by eye. This method corrects only for scale and not for tilt or height.

156. New Detail by Intersections and Proportional Dividers

See Fig. 30, page 59. On this figure suppose that the railway, church and wood are already shown on the map and that points D, E, F and G are identifiable on both map and photograph.

Suppose that C is identifiable on the photograph, but not on the map. It is one of the laws of perspective that a straight line on any plane remains a straight line on any perspective of that plane. However tilted the photograph may be, the map position of C will be found on the map at the intersection of the same lines as on the photograph. Supposing the position of A is required also. Then, if no intersection can be found nearer than C, fix C, and use the proportional dividers to fix A from C and G. By fixing C first in a way which corrects for both scale and tilt, as described above, the final error in the position of A may be much reduced.

This method is most important in sketching from air photographs.

157. Copying from Similar Figures

1. The copying and enlarging of maps by similar figures has already been explained (Chapter IX).

Now suppose that a map has been squared and that other

squares of the correct size have been drawn on paper ready for the enlargement. Suppose, further, that the map is set on an easel, not directly opposite, but at an angle to the axis of a camera, and is photographed in that position. On the photograph the map squares will no longer be square but of some lozenge form. Nevertheless, by inspection, an enlargement may be made from this distorted photograph of the map, correcting both for scale and tilt, because photograph and enlargement paper are covered with figures which, though not "similar," are perspectives of similar figures. This principle is then applicable in sketching from air photographs and it remains only to choose the most suitable type of "similar" figure. In enlarging a map the square with its diagonals (sometimes called the Union Jack method) is popular, because the map is generally squared or gridded, and diagonals are easy to draw. The photograph is not squared, however, and it is easier in this case to choose a figure with at least five sides, because it can then be subdivided to an infinite extent without measurement.

2. In Fig. 51, the points A, B, C, D and E form any pentagon. Join each point to all the others (see the broken



lines). Five more points (1 to 5) are immediately established by intersection and additional lines (dotted lines) can be drawn through them. There is in fact no limit to the number of dividing lines which can be drawn.

3. In Fig. 52, a, b, c, d and e are identified on the photograph as points A, B, C, D and E on the map. Inside this figure a stream is to be added to the map. The con-

struction includes the drawing, on both map and photograph, of the same lines in sufficient number to divide up the area into small figures, in which the detail may be copied by eye. The detail so copied will be corrected both for scale and tilt.



FIG. 52.

If, however, any chosen point (A, B, C, etc.) is considerably higher or lower than the average, the perspective truth will be spoilt and the result will be in error.

158. The Four Point Method

1. It sometimes happens that few points can be found common to map and photograph. Unfortunately no reliable work can be done unless at least four points can be so identified, but when those four have been found others can be fixed as follows: --- 2. If A, B, C and D be four points on the map and a, b, c and d be the corresponding points on the photograph, then, selecting one point as apex, join it to the other three, both on photograph and on map (Fig. 53).



FIG. 53.

If p is the point on the photograph which it is required to plot on the map, draw a line from the apex through p. Take a strip of paper with a straight edge, lay it on the photograph, transversely across the lines radiating from the apex, at any convenient distance from it, and roughly at right angles to the central radiating line, and mark the edge of the paper with a pencil "tick" at the points where the radiating lines cut the edge. Now transfer the strip of paper to the map, and lay it across the corresponding lines, turning the paper about until the three "ticks" corresponding to the rays joining the fixed points on the photograph come exactly over the corresponding rays on the map. Holding the paper in this position mark the map with a dot at the "tick" corresponding to the ray from the apex to the point P.

A line from the apex on the map through this point passes through the correct plotted position of the point P on the map. By repeating the process, using a different apex, a second ray is obtained, whose intersection with the first gives the position required. A third confirming ray can be obtained in a similar manner by using a third apex. The three rays should meet exactly in a point and give thereby a check on the accuracy with which the plotting has been carried out.

3. To plot a whole photograph, point by point, by this method is naturally very laborious and its principal value is therefore for plotting individual points required for a special purpose or for supplementing the original framework of fixed points to enable some particular photo to be plotted.

159. Correction for Height in using the above Perspective Methods

H

FIG. 54.

It has already been stated that no point should be used



In Fig. 54, P is a point on a hill appearing on the photograph at p (at or near the edge).

H is the height of flight in feet (Chapter XII, Sec. 88).

h the estimated height of P in feet.

D the distance of p from the centre of the photograph (in inches).



to be given to position of p.

Then $d = D \times_{H}^{n}$

Example: H=15,000 feet.

Then

h = 1,000 ,, D=3 inches. $d = \frac{3 \times 1,000}{15,000}$ =¹_E of an inch.

160. Adding Contours to a Map or Sketch

1. If only one single photograph is available, very little can be gleaned from it as to heights and contours (but see Chapter XII, Sec. 99, for hints as to the possibilities).

2. If an overlapping pair is available, the contours may be improved and amplified with the stereoscope. First of all the pair must be placed relative to each other, as described in Chapter XIII, Sec. 106, and pinned down. The ground is then seen in sharp relief. Examine the ground for watercourses or valleys (however small) which do not already appear on the map. Copy them on to the map lightly in pencil (they will not appear as streams unless water is actually flowing in them). The drainage system is now complete. Add to the map estimated spot heights on the spurs and under-features. Refer to Sec. 138 and Plates XXX and XXXI, which exactly illustrate the following stages, viz. :--

- i. Examine the existing contours and modify their shape (if necessary).
- ii. Interpolate contours half-way between, but take care to illustrate convex and concave slopes and remember that contours are evenly spaced on rivers and streams except near their sources, where the fall is generally concave.

161. Contouring a Photograph

It may happen that a vertical photograph is both an adequate and convenient illustration to a report. Its value will be much increased by adding contours or form lines sketched on by examining it in the stereoscope with other overlapping photographs.

The procedure is as follows :---

i. Pin down a "pair" as described in Chapter XIII, Sec. 106.

- ii. Pin a piece of tracing paper down alongside the right-hand photograph (for a right-handed draughtsman), so that it may either overlap the photograph, or be folded back clear (in order not to interfere with the stereoscopic examination).
- iii. Trace from the "overlap" portion of the photograph the streams and valley lines, tops of hills or under-features, and any other points requisite for a height control (Plates XXX and XXXI).
- iv. Add to the tracing any data regarding heights available from map, sketch, or measurement (with aneroid for example).
- v. Sketch in the bends of contours on streams.
- vi. Examine the stereoscopic image, folding back the tracing paper to do so, and replacing it at intervals to record short lengths of contours. Follow out every fourth contour in this way.
- vii. Transfer the completed contours (and short lengths) to the photograph, remove the tracing paper and complete the interpolation of the remaining contours directly on the photograph whilst examining with stereoscope. The interpolation, if every fourth contour (one, five, nine, etc.) has been carefully outlined as described above, consists of halving the interval, and then halving again, thus inserting three new contours between the two originals. As before, look for concave and convex slopes.

162. Form Lines on a Mosaic

Contours or form lines may be added to a mosaic on the lines described in the preceding section. A separate and extra set of the photographs used in the mosaic is, of course, necessary, and the overlap must be at least 50 per cent. in each case.



Sight Rule, Trough Compass, Clinometer, Aneroid, etc. $\label{eq:Plate XXXIII} P_{\text{LATE XXXIII}}.$

Plane Table.

[To face page 128.



CHAPTER XIX

DESCRIPTION OF INSTRUMENTS USED IN FIELD SKETCHING

163. The Plane Table

The plane table is a flat portable table (sometimes called "the Board") on a tripod stand (Plate XXXIII). The table proper can be dismounted from its stand for carrying, and is clamped to it for work. Before the clamp is finally tightened the table can be revolved and set (or oriented).

The portable pattern of plane table is 18 inches square and has telescopic legs. The R.E. pattern is 18×24 inches, with rigid legs. Both patterns are provided with waterproof covers.

In "mounting" the plane-table, if time presses, pin paper on to the board with drawing pins. If linen backed paper is available, use it. If time allows, however, mount as follows:-

Get some fine linen about 8 inches larger in each direction than the board. Lay it centrally on the board and cut out the corners and pieces where, when folded underneath, it will fall over the metal frame. Damp the linen slightly and paste (cornflour paste is the best) so as to adhere to the underside (not the top) of the board. Stretch the linen well whilst pressing on the pasted surface. Now take a piece of drawing paper of the same size as the linen, cut it as the linen was cut, damp it on the wrong side, paste the linen all over, and smooth the paper on to the linen. Put in some drawing pins on the underside. The board will be ready for use in 12 hours.

When dry the grid, corresponding to the co-ordinates of the control points, should be plotted on the board. When the control points are plotted correctly the board is ready for use.

The adjuncts to the plane table are the trough compass, the sight rule and the clinometer.

164. The Trough Compass

A 5-inch magnet is poised centrally in a narrow rectangular metal box, with glass face. The ends of this box are removable and fit over the glass face in order to keep it in position. The south-seeking end of the needle is provided with a small sliding collar by means of which "dip" is counteracted. On a metal plate at each end of the box there are engraved five one-degree divisions on either side of zero, which marks the lubber line, and an adjustment is provided whereby the needle is made to read equally on either zero. The side of the metal box is parallel to the line of zeros. A brass pin actuates a lever in the box which checks the swing, and the wooden case for the compass box has a sliding lid so designed that when pushed home it presses this pin and raises the needle off its pivot.

165. The Sight Rule, or Alidade*

The sight rule is the instrument used in setting the plane table or, alternatively, in drawing a ray to a point when the table has been set. It consists of a solid wooden rule, as shown on Plate XXXIII, provided with a hinged sight vane at each end. The edges of the rule are steeply bevelled, and are stamped with two scales, viz., (a) 2 inches to 1 mile, reading to 50 yards, and extending to 10,000 yards; and (b) a scale of inches, reading to 0.02 of an inch, and extending to twelve inches.

The rear sight vane is provided with a narrow slot, and the foresight with a broader slot down the centre of which is stretched a fine vertical wire or horse-hair, ending in two small holes, and secured by screws. The sight vanes in their working position stand up at right angles to the rule. They can be folded flat, to fit in recesses cut for them in the upper surface, before returning the rule to its leather case. For work in hilly country, where rays are often steep and the line of sight may not fall within the compass of the slots, a fine thread may be stretched between the tops of the sight vanes, in which holes are provided for the purpose.

The sight rule is provided with a leather case which can be attached to the plane-table tripod by a pair of straps. The weight of the sight rule in its case is 1 lb.

Telescopic alidades, or sight rules, are used in some important surveys, but are outside the scope of this manual.

166. The Indian Clinometer

This pattern of clinometer consists of-

- i. A base plate, 9 inches long, with three studs upon which it stands.
- ii. The level arm, in which is mounted a small spirit level, hinged to one end of the base plate and provided at the other end with a milled-headed

Some recent patterns of sight rule, unlikely to be met with on service, are provided with a parallel arm attachment. The parallel arm is a great help to accurate sketching, and the sight rules themselves, generally made of some aluminium alloy, neither warp nor chip so readily as the wooden patterns. For any important sketching at foreign stations, in peace time, the use of these metal sight rules is recommended. screw bearing on the base plate. This screw is for raising or lowering the end of the arm to level it.

iii. Two vanes hinged to the level arm at its extremities, and maintained in upright working position by steel springs. The rear vane, 4 inches long, is pierced at the top by a peep-hole, forming the back-sight. The forward vane, 8 inches long, is slotted centrally, and on the left edge of the slot is engraved a scale of degrees reading direct to 20 minutes. The zero of this scale is at the same height above the level arm as the backsight, and the graduations extend upwards and downwards to over 20°. On the right edge is another scale, graduated and figured with the natural tangents of the corresponding graduations of the degree scale and reading direct to 0.005. In some instruments the forward vane is fitted with a small carriage which carries an index wire and is moved up and down the vane on a rack.

The instrument is placed with open vanes on the plane table, or other flat surface and is directed at the object. The bubble is brought to the centre of its run by the milled-headed screw. The object is observed through the peep-hole and the graduation which is level with the object is read by eye direct; or, alternatively, the index wire on the forward vane may be run up on its rack until it cuts the object, and the graduation opposite the wire taken as the reading. The actual difference of height between two points is obtained by multiplying the distance between them by the natural tangent. The latter is read from the scale and the former is measured from the sketch.

167. The Abney Level

In this instrument a small spirit level, or bubble, is attached to a vertical arc graduated in degrees and rotating on a horizontal axis, which forms a transverse attachment to a small telescope. As an image of the bubble is seen in the field of view of the telescope when the level is horizontal, the instrument is very convenient to use. A scale of gradients sometimes accompanies the degree scale.

The instrument is held in the right hand and the telescope directed on the object so that the horizontal wire at the object end intersects the object. The vertical arc is then turned until the reflection of the bubble in the telescope is bisected by the wire. The angle of elevation or depression is read direct on the arc.

In some patterns of the instrument the graduated arc is

fixed to the telescope whilst the level is attached to a rotating arm operated by a milled headed screw. The end of the arm works over the arc and is marked with vernier graduations giving readings to ten minutes.

168. The Proportional Dividers

The proportional dividers (Plate XXXIV) consist of a double ended pair of dividers, held together by a pivot which can be slid up and down in a slot cut in the centre of each arm. This pivot can be clamped in any desired position. If the pivot is exactly in the centre, then, when the compass is opened, each pair of points is the same distance apart. As the pivot is moved to one end, so the distance between the points at that end is diminished in comparison to the distance between the points at the other end. Graduations show the ratio of the distance at one end to the distance at the other. The instrument is usually graduated on either side of the central slot both on front and back. These graduations are :—

- Left side on the front.—Setting to obtain the side of a square, from 1 to 10, or 1 to 1/10th of the area of a given square (Square).
- Right side on the front.—Setting to obtain the side of a cube, from 1 to 10, or 1 to 1/10th of the volume of a given cube (Cube).
- iii. Left side on the back.—Setting to obtain the side of a hexagon, octagon, etc., which can be drawn in a circle of any given radius (Circle).
- iv. Right side on the back.—Setting to obtain fractions of any given distance—viz.:—1/2 to 1/10th of the original; or multiples—viz.:—1 to 10 times the original (Linear).

Of these graduations No. iv is the only one of value in map (or photo) reading and field sketching.

If it is desired to obtain any particular ratio of reduction or enlargement, the setting may be obtained by making use of the graduations of scale iv. Generally, however, the problem is to enlarge or reduce, by some irregular ratio not given on the scale, and in such cases the correct position of the pivot must be found by trial and error. The chief uses of the proportional dividers are the linear reduction from air photograph to map, the adjustment of traverses and the enlargement of maps.

169. The Aneroid Barometer

The aneroid barometer depends for its action on the fact that the pressure of the atmosphere varies with the height above sea level. A surveying aneroid consists of a circular metal case, on one side of which is a glass protected dial,





over which moves a hand, or pointer, actuated by changes of atmospheric pressure (Plate XXXIII). On the dial there are usually two scales. The inner is a scale of inches corresponding to that of an ordinary mercury barometer and the outer a scale of feet based on the relation between atmospheric pressure (in inches of mercury), and the height above sea level. In sketching it is the outer, or "height," scale which is used. This scale is sometimes cut on a ring, which can be rotated by twisting a milled head similar to the winding knob of a watch. In another design the movable ring carrying this scale forms the upper part of the casing, the edge being milled for turning by hand, as in the setting circle of the prismatic compass. If the height of a place is known, the height scale may be set so that the pointer indicates that height, and a reading taken at any other place. will then indicate the height of that place. Generally speaking, the larger the aneroid the more accurate it is. For sketching, a 21 or 3 inch diameter aneroid will suffice. The height scale of these sizes usually has a range of from 0 to 6,000 or 10,000 feet, with divisions of 50 feet. Heights may be estimated to 10 feet.

170. Method of using the Aneroid Barometer in Hasty Sketching

Owing to the changes of atmospheric pressure, which are described later, a barometer cannot be relied upon to give accurate results. It will, however, give the approximate difference in height between stations at which readings are taken and the shorter the time that elapses between readings the more accurate will be the values obtained. The barometer is, therefore, often useful in sketching, more especially on small scales where a large V.I. is being used. Whenever possible the first and last readings should be made at points whose heights are known. An adjustment can then be made to all the intermediate readings.

For example : starting at a point A whose height is known to be 510, the barometer is found to read 620. At the end of the sketch, 5 hours afterwards, the barometer reads 340 at B, whose known height is 180. At the start the barometer was reading 110 too high, and at the close 160. The difference of 50 feet is spread over 5 hours, and the final correction will be made up of the starting error of 110, plus 10 feet for each hour after the start.

The procedure outlined above may be necessary when time presses, or with new and untried barometers. It is too uncertain to be sound in more deliberate sketching. The following paragraphs should be studied by those who may have to sketch a considerable area.

171. Conditions that affect Barometer Readings

Since the Aneroid Barometer depends for its action on the pressure of the air, any intermediate change in atmospheric condition will affect the difference in height, shown on the dial, between two stations.

Changes of air pressure are due to the following main causes :---

i. The diurnal variation.

ii. A general change of weather.

iii. A change of temperature.

Of these the diurnal variation only will be discussed here, as corrections due to it can be applied easily and without loss of time. A gradual change of weather will not affect the barometer to any appreciable degree during a day, although a sudden disturbance, such as a thunderstorm, will. At such a time the barometer is most erratic, and its irregular movement cannot well be allowed for. The effect of change of temperature is considerable, especially during rapid changes of altitude. Correction for temperature is quite possible, but will not be considered in connection with sketching.

Barometer No.	Place.	Date.			
Time.	Reading.	Correction to Zero.			
6.00	1880	- 60			
.30	1875	- 55			
7.00	1870	- 50			
.30	1860	- 40			
8.00	1845	- 25			
.30	1830	- 10			
9.00	1825	- 5			
.30	1820	Ő			
10.00	1825	- 5			
.30	1835	- 15			
11.00	1850	- 30			
.30	1875	- 55			
12.00	1890	- 70			
30	1915	- 05			
13.00	1935	-115			
30	1945	-195			
14.00	1955	-125			
30	1960	-140			
15.00	1965	-145			
30	1965	-145			
16.00	1965	-145			
.30	1965	-145			
17.00	1960	-140			
30	1960	-140			
18.00	1950	-130			
	FIG. 55.				

The effect of diurnal variation is that readings taken at a

* In the tropics thunderstorms and heavy rain are common in the afternoon, and at such times barometric readings are unreliable.

station every hour, or half-hour, throughout the day will vary up to 120 or 150 feet. Fig. 55 shows a set of readings taken at the same station every half-hour from 0600 hrs. to 1800 hrs. It will be seen that the lowest altitude reading, which corresponds to the highest barometric pressure, occurs at 0930 hrs., and taking this reading as zero, Column 3 shows the amount by which the other readings are too high. In Fig. 56 the values of Column 3 have been plotted graphically against their respective times, and a more or less regular curve results. This curve is called the *daily wave* of the barometer used, and any reading of that particular barometer may be corrected by subtracting the value of the wave at the time at which the reading was taken (Fig. 57, Column 4).

It will be found that curves plotted over a period of several days retain the same distinctive shape, but show slight variations in detail. If a series of such curves are combined, a mean and more reliable curve results. A barometer "wave" will vary slightly with the season of the year and perhaps even more so with locality. The waves of different barometers have the same general shape, but show individual differences, which may be most noticeable where different makers are in question. A "wave" graph (stating where, when and for what barometer it was made) should therefore be prepared for each instrument, and kept in the leather case of that instrument. New wave graphs should be prepared at definite changes of season or locality.

172. Precautions to be observed when using a Barometer

The following precautions should be taken :---

- i. It should not be used near the limits of its range.
- ii. It should be tapped gently with the fingernail or with a pencil before reading. A sharp blow may injure it seriously.
- iii. As there is a considerable "lag," or delay in coming to the correct reading, it should not be read immediately after a rapid change of altitude.
- iv. It should always be read in the same horizontal or vertical position.
- v. As the needle is some distance above the scale, there is danger of parallax unless the eye is kept always in the same relative position to the needle.
- vi. It should not be used, or at any rate not trusted, during a thunderstorm.

173. The use of a Barometer in Deliberate Sketching

An example of booking and correcting the barometric readings taken during a traverse is given in Fig. 57. A



"wave" had been prepared for the particular instrument used. The use of the various columns, and the explanation of the figures contained in them will be clear from the succeeding paragraphs.

When the height of one point is known (Station 1 in this case) the proper correction to the provisional height (Column 5) is obtained directly, and is applied to the provisional heights of other Stations. The deduced heights are thus obtained (Column 7).

Owing to gradual change of pressure, as distinct from the "wave" correction, two readings, one on arrival and one on departure, must be taken at any station at which a stay of

1	2	3	4	D	6	7	8	9
Station Number or Point of Detail.	Time.	Barometer Reading.	Wave Correction.	Provisional Height.	Provisional Adjustment.	Deduced Height.	Final Adjustment.	Final Height.
85	15.30	3560	145	3415	-	1293	+48	1341
43	07.20	3030	45	2985		863	+25	888
River	07.10	2870	47	2823		701	+25	726
Bank 42	07.00	2920	50	2870		748	+24	772
35	06.10	3100	59	3041	1 million	919	+22	941
34	06.00	3070	60	3010	-2122	} 888	+21	909
34 33	16.30	3130 3490	145	3345	-2001	1248	+21	1269
21	09.15 09.00	3320 3160	13	3319 3157	-2097	1222 1060	$+ \frac{1}{0}$	1223 1060

FIG. 57.

more than half an hour is made. Thus at Station 34 work was stopped for the night. The reading on arrival gave a provisional height of 2,985 feet, and when work started again next morning, the provisional height from a new barometer reading, corrected for "wave," was 3,010. The difference (+25) was applied to the provisional adjustment (Column 6).

When the heights of two or more stations are known they are used for adjusting the deduced heights (Column 7). In this example the heights of Stations 1 and 85 are known, and it will be seen that at the latter station the deduced height is 48 ft. too low. This closing error must be adjusted through the intermediate stations in proportion to the time that has elapsed. The total time in traversing between Stations 1 and 85 was 17 hours ($7\frac{1}{2}$ hours the first day, and $9\frac{1}{2}$ hours the second), and the closing error was +48 feet. The adjustment was, therefore, approximately +3 feet per hour; *i.e.* at Station 42 (8 hours from Station 1) it was +24 ft. Column 8 shows this adjustment, and Column 9 the final height.

Readings must be taken at all possible points of known height, even when they do not form part of the sketch. Adjustments obtained in this way are most useful in counteracting the effect of changes of pressure and of temperature.

If a barometer with a movable height scale is used, Columns 5 and 6 are unnecessary. The scale may be set to read the assumed (or known) height, corrected by the wave value for the time of starting.

In hot countries and the tropics generally, the altitude scale on an ordinary aneroid meant for use in the temperate zone underestimates owing to the air being lighter.

In such cases, if precise local information is not available, a correction may be applied to all altitudes consisting of 10 per cent. of the difference between the altitude of a station in Column 7 and the altitude of the initial station. This correction will be positive if the station is above the initial one and negative if it is below it.

APPENDICES

APPENDIX I

FINDING TRUE NORTH FROM SUN OR STAR

 True North by Compass.—True North is readily obtained from magnetic north if the variation of the compass is known. The compass, magnetic variation and the finding of true north in this way have already been explained in Chapter VI.

2. True North by Watch and Sun.—Lay the watch flat with the hour hand pointing to the sun. In the northern hemisphere the direction of true south is then midway between the hour hand and XII. In the southern hemisphere point XII to the sun; then true north lies midway between XII and the hour hand.

Thus, in northern hemisphere, time 1500 hrs. With watch set as described above, south lies in the direction midway between the figures 1 and 2 and north in the opposite direction.

This method is very rough. It is of no use in the tropics. The further away from the equator the more accurate it becomes. Replacing the watch by a 24-hour dial drawn on the sketch does not make for much greater accuracy in the absence of a special device. If summer time is in force correct the watch before taking the observation.

3. True North by the Sun.—The method described below is one of "Equal Altitudes." Drop some sealing wax on a penny and press down thereon the flat end of a pencil, taking care that the latter is truly upright and central on the face of the coin. Place the "style" so formed on a table in the open, to which a square of white paper is pinned. Run a pencil point round the coin and find its centre O (Fig. 58). At about 10.00 note that the shadow of the pencil's point is at A. Mark A and join it to O and with OA as radius draw the circle C around O. Note that as the sun moves the shadow at the same time traces an arc (dotted, Fig. 58).

At about 13.45 examine the shadow again ; note that it is again approaching the circle. At about 14.00 the apex of the shadow again crosses the circle ; mark the point of crossing, B. Then ON, which bisects the angle AOB, is the direction of true north in the northern hemisphere, or true south in the southern hemisphere. The reader can improve at will on this crude arrangement, and can experiment on the ground with the shadow of the corner of a roof suitably situated or with a pointed stake set at a slight angle in the ground. The centre of the circle C in these cases is vertically beneath the edge of the roof or the point of the stake ; in the latter case it may be obtained by aid of a weighted string or plumb-bob.

If the observer's position be not too near the poles, the apparatus be suitable and care be taken with the working, it



is possible to obtain true north with considerable accuracy by this method.

4. True North by the Stars.

1. Northern Hemisphere—The Pole Star (Polaris).—Everyone should be familiar with the Pole Star. It is the bright star indicated by the two "Pointers" of the Great Bear or Plough, Fig. 59.

Polaris gives an approximate line to true north. In latitudes less than 60° it is never more than 24° in bearing from the Pole. All stars revolve round the Pole and twice in the 24 hours Polaris is in the meridian, *i.e.* truly north. Midway between the times when it crosses the meridian, Polaris is approximately at its extreme distance, *i.e.* 2° about lat. 45° , east or west of true north. There are two easy ways of knowing when Polaris is in the meridian : the first, by means of stars in the constellation of the Great Bear ; the second by stars in Cassiopeia, which is a conspicuous group, shaped like the letter W (Fig. 59) on the opposite side of the Pole Star from the Great Bear.

The Pole Star is exactly north when the point half-way between the two end stars of the tail of the Great Bear is vertically above or below it; and the same is true for the point half-way between the two stars which form the first stroke in the W of Cassiopeia. Note this line of points, as pecked in Fig. 59, passing through Polaris.

As the height of the Pole, in other words the latitude, increases, Polaris becomes of increasingly less value as a means of finding true north.

2. Southern Hemisphere—The Southern Cross.—The Southern Cross may be used as follows: Consider the Cross as a kite; prolong the greater axis 4¹/₄ times in the direction of the tail, and the point reached will be approximately the South Pole. If a piece of paper be marked off along its edge by 12 dividing lines, spaced equally, and be held so that the first and third scale lines coincide with the head and tail stars respectively, the intersection of the 12th line with the edge of the paper will give, approximately, the southern Pole.

The southern Pole is more difficult to fix than the northern, as there is no bright star near it.

3. Southern Cross and Hydrus.—Continue the line above described for another two lengths of the greater axis of the Cross, *i.e.* to the 16th line of the scale; we thus reach a star named β Hydri, which of the bright stars is the nearest to the South Pole.

When a Crucis, in the tail of the kite, and β Hydri are in the same vertical, they are nearly in the meridian and thus mark true south.

APPENDIX II

NIGHT MARCHING

1. General.—Night marching even under the best conditions demands long practice and care on the part of the guide. Unless the guide has a knowledge of elementary astronomy and tables to give him the correct bearing of the stars, the direction of a night march in a country unknown and unmapped or featureless must be maintained by compass, luminous for dark nights.

2. Marching on a Compass Bearing .- The guide must know

the bearing on which he wishes to march. He then observes some object which has the required bearing and marches towards it.

In the Service Prismatic Compass the magnetic north is marked by a broad luminous arrow-head. The glass cover is turned until the setting-vane on its rim, corresponding to the luminous direction mark on its glass, points to the required magnetic bearing as shown on the external ring; the cover is then clamped at this bearing. The box is now held so that the direction mark is superimposed on the arrowhead, in which position the line of the luminous patches in the lid, fully extended, indicates the line of advance.

In the liquid type of compass the bearing may be read directly at night with the same exactitude as by day; but in night marching some of this accuracy is unavoidably lost and marching on the pointers is in general sufficient.

As a rule, the darker the night the greater the assistance afforded by the luminous paint. During a moonlight night a luminous compass may be of no greater value than an ordinary compass with a clearly marked north-point.

3. Prolonging the Compass Indication.—It is often difficult to identify an object ahead on the correct bearing. A stick painted white or with white paper pasted on it, or best of all, one prepared with luminous paint, may then be useful. The operator, standing perfectly steady, should wait until his compass has come to rest, and then hold the stick, at an angle of 45° to 60° with the horizontal plane, in the direction indicated by the line between the luminous patches in the compass-lid.

With the stick thus held it is easy, except on very dark nights, to pick up some object on which to march; the advance is continued until the guide considers it desirable to halt and allow the compass to settle so as to observe the direction of advance afresh.

The object may be terrestrial or it may be a star. If it is terrestrial the march can be continued until the object is reached, when a new point must be chosen. If the object is a star, it must be remembered that the bearing of a star, except one close to the Pole like Polaris, is constantly changing. An advance can be continued on a star for 10, 15 or 20 minutes according to its position in the heavens.

4. Celestial Objects.—The most convenient stars to select for marching on are those which happen at the time to have an altitude of from 15° to 30° ; stars below 15° may become lost in haze, whilst for those above 30° the head has to be inconveniently raised. Speaking broadly, a star at these altitudes will rarely move more than 5° in azimuth (*i.e.* to a flank) in 20 minutes. Hence if at the end of every 15 to 20 minutes the observer halts and takes a fresh bearing, he can count on keeping direction correctly.

Although it is of assistance to an observer to know the stars, it is not necessary that he should study them. Anyone can, with care, march on a compass bearing with the stars as points to direct him, although he may be totally ignorant of the names of the stars or even of the constellations. The great point is to be sure that the compass bearing is correctly taken and prolonged, and that the star selected is adhered to until a change is required.

In civilized and well-mapped countries the use of stars for keeping direction is not likely to be necessary. In uncivilized country on the other hand, the method may be of great value. Any officer to whom such a task would be likely to fall would be wise to acquire an elementary knowledge of astronomy.

5. Marching by Compass when no Objects are Visible.—It may happen that, owing to clouds or fog, no terrestrial objects on which to march between halts are visible; then the only safe way is for an assistant to stand behind the observer and work as follows: The guide with the compass and luminous stick, as soon as the compass becomes steady, gives the word "steady." The assistant, carefully noting the alignment of the luminous stick, then advances in what he judges to be the right direction, until the guide halts him before he is lost to sight, by giving a low whistle.

The guide, having thus halted his assistant, notes by means of the compass whether the latter is standing on the true line of advance or to the right or left of it. He then moves up, and placing himself on what he judges to be the correct alignment, sends forward his assistant again.

The rate of advance obviously depends on the distances covered between halts; after the first few advances the assistant will have ascertained the number of paces he can safely take without being lost to sight, and on reaching that distance he will halt without waiting for the whistle. This is important, since the whistling might attract attention when close to the objective.

Slabs of cardboard or wood prepared with luminous paint, are of great assistance in this tedious process of sending on an assistant; a slab 12 inches square can be seen at from 30 to 200 yards distance, according to the condition of the atmosphere and the paint, and by this means the rate of advance can be greatly accelerated.

Besides the guide and his assistant, a third person should be employed to keep a careful record of the distances traversed.

It may be useful to remember that a constant error of 5° in bearing causes a deviation from the course of 150 yards per mile of march.

APPENDIX III

SPELLING OF PLACE NAMES

 Spelling.—There is no geographical subject which has given rise to more discussion and to greater differences of opinion than that of the spelling of names, and it is desirable that officers should have some acquaintance with the principles involved. It is a matter which affects not only maps, but also official reports and handbooks.

When a country uses the Roman characters there is no difficulty. Clearly the name must be spelt as in the country of origin unless there is an anglicized form in common use, *e.g.* Florence for Firenze, when the form adopted would be a matter for consideration in each case. The question of transliteration does not arise.

2. Transliteration.—When, however, a language does not use the Roman character, the names must be transliterated for English use. Such languages are Russian and Bulgarian which use the Cyrillic character, Arabic and Persian which use the Arabic character, Hebrew, Greek, Chinese, and many other Eastern languages. In Russian, Arabic, Hebrew and Greek it is possible to prepare tables showing how each letter should be transliterated so that an Englishman should pronounce the word in its new form as nearly as possible as it is pronounced in the country of origin.

Whatever system of transliteration is used it is evident that only a small measure of success can be obtained. The letters do not, as a rule, correspond exactly with the English letters; and even if they did, the fact that there may be several different ways of pronouncing the same letter would make a perfect representation of the sound impossible. It is easy to see that the transliteration, letter by letter, of the English words through, though, and tough, would give a foreigner no guide to the pronunciation of more than one of them.

3. Principles of Transliteration.—For better or worse, however, names have to be transliterated, and rules for doing so have to be devised. These fall into two parts :—

- i. The sounds to be attributed to each letter of the English alphabet must be laid down and adhered to for the transliteration of all languages.
- ii. A table has to be drawn up for each language which it is desired to transliterate, showing what letters of the English alphabet, employed as in i, are to be used for each letter of the foreign alphabet in question.
For i, a new set of rules has recently been drawn up by the Permanent Committee on Geographical Names at the Royal Geographical Society on which the War Office and several other Government departments are represented. It is printed below. It differs but little from the Knox rules which have been followed for many years by the Geographical Section of the General Staff, which themselves were almost identical with the old rules of the Royal Geographical Society, based on the Washington system of the Admiralty. These rules aim at rendering sounds *approximalely* only, without having recourse to the elaborate symbols, used by phoneticians, and unsuitable for maps.

4. R.G.S. II System, 1924

Rules for the Spelling of Geographical Names for British Official Use

1. The spelling of every place-name in an independent country or self-governing dominion using the Latin alphabet * shall be that adopted by the country or dominion, except in the case in which certain important localities have also, in addition to the official name, another customary name, notably different, in which case the name customary in British use (*i.e.* "conventional") may be adopted (*e.g.* Geneva, Warsaw, etc., for Genève, Warszawa, etc.).

2. In colonial possessions the spelling of such place-names as belong to languages coming under Rule 1 will be spelt in accordance with that rule.

 The accents and diacritical marks in official use by the above countries will be retained. Wherever it appears desirable, the pronunciation will be shown by giving the name as transliterated on the system below.

4. All other place-names throughout the world will (with the exception of "conventional" names and some others) be spelt in general accordance with the following system.

The broad features of this system are :--

- i. That vowels are pronounced as in Italian and consonants as in English;
- ii. That every letter is pronounced, and no redundant letters are used.

The system aims at giving a close approximation to the local pronunciation; but it is recognized that in some languages, notably Russian, Greek and Arabic, the necessity for letter-for-letter transliteration often renders this impossible.

ĸ

Including "Latin " alphabets containing extra or modified letters, such as Czech, Crotian, Polish, Romanian, etc. The pronunciation of these letters is given in the " Alphabets of Foreign Languages," etc., mentioned below.

TABLE OF SPELLING AND PRONUNCIATION, R.G.S. II

a ä	Long and short, as in <i>lāvă</i> As in <i>fat</i> ; rare except in Teutonic	Somāli, Bukhāră.*
ai†	languages. The sound of the two Italian vowels; frequently slurred over, almost as	
	in Eng. aisle, ice	Wadai ; Shanghai.
au	The two Italian vowels; frequently slurred, almost as ou in out	Sakau ; Bauchi.
aw	when followed by a consonant, or when terminal, as in awl, law	Dawna, Saginaw.
b	As in English.	Kandahar, Serang,
C	by k or s; except in the com- pound ch, and in many conven-	
	tionally spelt words, as	Calcutta, Celebes.
ch	this sound	Chad, Naroch.
dh	Soft th as in they : a slight d sound	
un	sometimes preceding it in Semitic	The same of the
	languages	Dhuvu; Riyadh.
e†	Long as in eh ?; short as in bet. (For the e sound in the French je, see note at end on the "neutral	
	vowel")	Gēlo; Mafĕking.*
(ee)	Used for i (q.v.) only in a few con- ventional names	Darjeeling, Keelung.
ei†	The two Italian vowels, frequently slurred	Beirut, Raheita.
(eu)	Not used as a single sound	
í	As in English; ph must not be used	
	see ph)	Mustafa, Maidan-i- Naftun.
g	Hard, as in gel, gift ; never as in gem,	and the state of the second
	gin	Gedáref, Gilgit.
gh	Soft guttural, the Arabic ghain (\mathcal{E})	Dagh, Baghdad.
h	Used only when sounded; or in the compounds ch, dh, gh, kh, sh, th,	
	sh	Ahmadabad, 'Abdul- lah.
i	Long as in marine; short as in piano (not as in pin)	Fiji; Kibonde.*
j	As in English; except in translitera- tion of Russian, Bulgarian, and Chinese, where it equals <i>zh</i> , or the	in the second
	French j §	Juba, Ujiji (Eng. j); but Jitómir, Jelezna, Jao-ping (Fr. j).

* The long and short symbols given here are merely for explanation, not for use.

not for use. † Pronounced differently in Greek: see "Alphabets of Foreign Languages transcribed into English according to the R.G.S. II System "(published by the Royal Geographical Society). ‡ See note at end on Liquid Sounds, § This decision has been arrived at owing to the large number of English (and French) maps of these countries in which the sh sound

appears as j.

TABLE	OF SPELLING AND PRONUNCIATI	ION, R.G.S. II-contd.
k	As in English : hard c should never be used (except in conventionally spelt words)—thus, not Corea,	
kh	Hard aspirated guttural, as in the	Korea, Kabul.
1*1	Scottish toch (not as in lock)	Khan, Sebkha.
m * }	As in English.	
ng	Has three separate sounds, as in vanguard, finger, and singer. If necessary to distinguish, in the first and third forms a hyphen may be placed, as van-guard, sing-er	In-gássana ; Bongo,
0	Long as in both [†] ; short as in rotund	Angola, Kigoma : Angora Hondhulu *
õ	As in German; equals the French eu in peu; or nearly the English sound in fur	Câmle Venikăi
oi*	The Italian vowels; sometimes slurred as in <i>oil</i> . If necessary for pronunciation, a hyphen may	Gome, remain
(00)	be inserted, as in Tro-itskoi Used for u (q.v.) only in a few con- ventional names, chiefly Indian	Hanoi
ou*	Dissyllabic, and not as French or	Poona, Foochow.
ow	Represents, as a diphthong, nearly the <i>au</i> sound (above) <i>only</i> in the romanization of Chinese. Con-	Ziatoust.
	As in English	Hankow,
ph	As in loophole; not to be used for	
	the f-sound, except in Greek	Chemulpho; Paphos.
P	Represents only the Arabic Qaf (ق): i.e. a guttural k	Oena, 'Irag,
qu	Should never be employed to repre- sent the sound of kw: thus, not	Namahura Kworra
r§	As in English; should be distinctly pronounced.	Namakwa, Kworra.
S	As English ss in boss, not as in these or pleasure.	
sch	As in discharge, the s distinct from ch	Ruschuk.
sh }	As in English.	
th	Hard th as in thick, not as in this	Tharmida.

Pronounced differently in Greek: see "Alphabets of Foreign Languages transcribed into English according to the R.G.S. II
 System "(published by the Royal Geographical Society).
 † The true Italian ô is broader than this: almost as in broth (=R.G.S. II aw).
 ‡ The long and short symbols given here are merely for explanation, por for use.

not for use.

§ See note at end on Liquid Sounds.

TABLE OF SPELLING AND PRONUNCIATION, R.G.S. II-contá. Long as in rude, or as oo in boot : u short as in pull Zūlū ; Rŭanda." Represents the French u, as in tu Üsküb. ñ (Fr.) v As in English. w Always a consonant, as in yard; it should not be used as a terminal Kikuyu, Maya. x vowel, e or i being substituted; e.g. not Kwaly or Wady, but Kwale, Wadi. As in English gaze, not as in azure. As the s in treasure, the z in azure, or the French j in je ; but for the zh sound in Russian, Bulgarian, and Chinese use j (vide note above ... Zhob, Azhdaha. under i) NOTES. The doubling of a vowel or a consonant is only necessary when there is a distinct repetition of the single sound, and should otherwise be Nuulua, Moorea, Jidavoided ... da, Muhammad, Accents should not generally be employed ; but in order to indicate or emphasize the stress, an acute Saráwak. Qántara, accent may be used ... Tong-atábu, Paraná. A long or short mark over a vowel (e.g. ā, ŏ) should only be used (and that sparingly) when without it there would be danger of mispronunciation Kūt, Hashin, Angora. *** Hyphens will not be used except to indicate pronunciation and with

* The long and short symbols given here are merely for explanation, not for use.

Mus-hil, Pusht-i-Kuh.

the Persian izafat ...

† Pronounced differently in Greek: see "Alphabets of Foreign Languages transcribed into English according to the R.G.S. II System" (published by the Royal Geographical Society).

Inverted Comma and Apostrophe.—The inverted comma 'is employed only to represent the Arabic 'ain E, and the Hebrew 'ayin y The apostrophe ' in foreign words indicates a liquid sound (see below). Liquid Sounds.—The occasional " liquid " or " palatalized " sound

Liquid Sounds,—The occasional "liquid" or "palatalized" sound of d, i, n, r, i, tc. (as in d'you,*luve, new, clarion, tune, etc.*) is as a rule sufficiently represented by a following <math>y; where, however, owing to a following consonant, or to the letter in question coming at the end of a word, the y is inapplicable, the liquid sound will be represented by an apostrophe, thus; d, l', n', r', l', etc. The "Neutral Vouci."—The "indeterminate" or "neutral" vowel

The "Neutral Vouel,"—The "indeterminate" or "neutral" vowel sound (er), i.e. the sound of a in marine, e in often, i in stir, io in nation, o in connect, ou in curious, u in difficult, etc., e in French je, or the often unwritten vowel (\checkmark Fat-ha), in Arabic, etc., is represented as a rule by a: as in Basra, Hawiya; but sometimes by e, when the sound approximates more to e than to a: as Meshide, El Gerira. (In any guide to pronunciation issued by the Permanent Committee on Geographical Names, the "neutral vowel" is represented generally by the italic e: occasionally also be italic a or u.)

This sound must not be confused with e-mule, where the e is not sounded at all : as in Abbeville.

Nasal Vowels.—In illustrating the pronunciation of French, Portuguese, Polish, etc., nasal vowels, the nasalization will be represented by italic n: as Częstochowa, pr. Chämstokhóva.

5. Special Rules for Certain Languages.—It is hoped that in future the system given above will be universal. Even if space permitted it would not be necessary to print here the transliteration tables for each language. The R.G.S. has published a book of "Alphabets of Foreign Languages transcribed into English according to the R.G.S. II System," but it is too much to hope that they will be universally adopted. The surveys of India and Egypt have their own systems for transliterating, and any change of system would involve many alterations in existing maps.

Although the use of these rules and tables involves a transliteration letter by letter which is designed to give the best approximation possible to the pronunciation, an expert in both languages will constantly be aware that the transliterated form does not represent the sound, and may feel tempted to improve on it; but usually the results must be accepted.

6. Unwritten Languages.—The pronunciation table printed above is equally essential for arriving at a suitable form of spelling names in unwritten languages, such as those in tropical Africa or the Pacific. Here sound is the only guide, and the object aimed at is to represent the name so that it will be pronounced correctly by an Englishman. Even so, certain spellings which contradict the R.G.S. II System have become conventional, as the use of th to render the sound of dh in Fijian. It is evident that no system of transliteration will enable a name to be correctly pronounced by people of different nationalities.

7. Chinese and Japanese.

1. It is very desirable that officers to whose lot it falls to ascertain by word of mouth and to record names should follow the rules here given. Certain languages require special treatment. For instance, Chinese and Japanese are written languages but have no alphabet. It is therefore necessary either to treat them as unwritten languages and be guided by sound only, or to prepare elaborate tables giving the Roman lettering, to be used for each syllable or symbol. This was done for Chinese by Sir T. Wade, and his system has been that most generally used ever since. The Directorate General of Posts publishes a list of Post Offices in China, with its own system of spelling which is not always consistent. The Permanent Committee on Geographical Names proposes to follow the Post Office List for Chinese (but not for Turki, Mongol, etc.) names, as far as it goes, and to adapt the spelling of other Chinese names to the Postal system, such as it is.

2. A similar system has been prepared for Japanese by Mr. Hepburn; but the Japanese publish official maps giving the names in Roman lettering, and these would presumably be accepted. The Land Survey Department has, however, recently introduced a new system of spelling which differs considerably from the well established system used by the Imperial Geological Survey. Greek also has to be specially treated, for the Greek alphabet is so familiar that it is usually more useful to be able to recognize the original letters than to put the name into a strange form even if that form gives the correct pronunciation. Thus the letter ϕ is always transliterated by ph and not by f.

8. Double Transliteration.—Many other difficulties arise. For instance, a name of Russian origin may appear on a map transliterated into German. To get it in its correct form by our rules it would be necessary to put it back into Russian and then transliterate it afresh as Fr. Tchernigov, Ger. Tschernigow, Eng. Chernigov. Native names in Africa and elsewhere are transliterated by other Powers according to their own rules and pronunciation, and a fresh transliteration is required for an English map. Examples are :—

Fr. Ouadi, Djebel; Eng. Wadi, Jebel; Ger. Kilimandscharo, Ssonjo; Eng. Kilimanjaro, Sonyo; Port. Inhambane, Cuango; Eng. Nyambane, Kwango.

APPENDIX IV

MAKING A STRIP MOSAIC

1. It may occur on Service in relatively unmapped areas, that a mosaic of air photographs is the only possible form in which to illustrate the tactical situation. Speed is the essence of such a situation, and no time can be spared for the more elaborate methods required in mapping. A mosaic can be made quickly providing that :---

 Flying has been consistently good and the area has been covered in strips. Haphazard photography varying in scale, and with no definite sequence, is of no value unless both time and an enlarging lantern are available. ii. No attempt is made to secure a fit everywhere— Photographs of anything but a flat plain cannot fit everywhere.

iii. Each strip is properly oriented—Haphazard orientation implies gaps or overlaps between strips.

iv. The area does not include large differences of height (say 1/10th of height of flight). The more hilly the country the worse will be the fit between photographs.

2. Whether the mosaic is to be composed of several strips, or only of one, the method of building up each strip from the series of photographs on which it is based, will be the same, and, for others than trained surveyors, the following method is the best way of doing so quickly and accurately.

3. Each strip should be made up as follows. First mark the centres of the photographs composing the series. In many cameras a cross is already photographed in the centre.



Photographs ready for cutting. See para. 8. Fig. 60.

In others marks are made on the edges of the photograph which when joined give the centre. Failing this, draw the diagonals of the photograph and take their intersection as the centre. Call these centres from left to right, P_1 , P_2 , P_3 , etc.

4. On the first (say the left hand) photograph select two points lying towards the right edge, and above and below the centre. The points chosen must be visible on the overlap portion of the second photograph (Fig. 60). Call these points A and B on the first photograph, and a and b on the second. Mark all four points with a pin-prick.* Now on the second

• The best results will be obtained if points A and B are, as shown, roughly equidistant from P_1 and P_2 . C and D roughly equidistant from P_2 and P_3 , etc. If any pair of points is much nearer to one centre than the other, fresh points should be selected and the rest of the tracing redrawn. It is essential that the points chosen should be roughly on the general level of the country. If any hill summit, or any point in a deep ravine, is chosen the orientation will be swung.

photograph select similarly two corresponding points C and D, and transfer them to the third photograph as c and d. Continue this process right through the series. There will now be marked on each photograph except the first and last, its own centre and four other points.

5. Take a piece of tracing paper long enough to cover the made-up strip. Place the first photograph under the left-hand end of the paper and mark on it the positions of P_1 , A and B. Slip out the first photograph and insert the second photograph so that A and B on the paper coincide as nearly as possible with a and b on the photograph. Keeping it in this position mark on the paper the positions of P_2 (the centre of the second photograph), and of C and D. Slip out the second photograph, insert the third photograph and treat it similarly. Continue this process throughout the series.

6. Remove the tracing paper, and on it draw lines joining



Appearance of tracing-paper. See para. 6. FIG. 61.

 P_1-P_2 , P_2-P_3 , etc. The paper should now present the appearance shown in Fig. 61.*

7. Replace the first photograph under the paper so that P_1 , A, and B on the paper coincide with P_1 , A, and B on the photograph. On the line P_1-P_2 on the paper prick through a point near the edge of the photograph. Remove the paper, and on the photograph draw a line joining its centre (P_1) to this pin-prick. Carry this line right across the photograph, dotting it from P_1 to the left.

8 Slip out the first photograph and insert the second photograph, so that P_2 and the other markings on the photograph coincide with those on the paper. Transfer the lines P_1 - P_2 and P_2 - P_3 on to the photograph in the same way by

^{*} Unless the tracing paper is of good quality it may be necessary to mark each point with a cross in coloured ink to make it more visible.

pricking through points lying on them. Continue this process throughout the series. All the photographs except the first and last should now have two lines running through their centres. The appearance of the first and second photographs is shown in Fig. 60.

9. Should the overlap common to each pair of photographs in the strip be 50 per cent. or more, this process may be much simplified, and the two lines required on each photograph obtained without the use of tracing paper. Instead of proceeding as in paragraph 4, observe on the first photograph where its centre P1 lies in relation to the detail surrounding it. Now turn to the second photograph which will show the same detail near its left edge, and by inspection mark the point where P1, the centre of the first photograph, falls. Carry on this process throughout the strip, transferring on to each photograph the centres of the photographs lying to left and right of it. When this is done each photograph except the first and last will have marked on it three points: its own centre, the transferred centre of the photograph to its left, near its left-hand edge, and the transferred centre of the photograph to its right, near its right-hand edge. The first and last photographs will naturally have only two points marked on them.

On each photograph draw lines joining the centre to each of the other two points. These are the same lines as those obtained by the methods described in paragraphs 4 to 8, and shown in Fig. 60.

10. On the first and second photographs select in the common overlap a point of detail lying on the line P_1-P_2 , and roughly equidistant from P_1 and P_2 . Prick through this point of detail on both the photographs. Pin down the first photograph with push-pins or drawing-pins to a sheet of mounting board or cardboard. Now place the second photograph overlapping the first so that the two pin-pricks coincide, and so that the lines common to both photograph are exactly superimposed. Pin down the second photograph and add one by one the remaining photographs of the strip.

11. Take a razor or sharp knife, and a straight-edge, and cut through the overlap of the first two photographs on a line passing through the coincident pin-pricks and roughly at right angles to the line P_3 - P_2 . Continue this process throughout the strip. Each photograph except the first and the last will now have been cut into three pieces. Take out the pins, pick out the centre piece of each photograph and throw away the outer pieces. Paste down the centre pieces to a mountingboard or stiff paper; they will join along the cut edges. Remember that the detail—roads, hedges, etc.—should match exactly on and near the lines joining the centres of the photographs, but that towards the top and bottom of the strip there will usually be distortions of various kinds and the detail on each side of the cut will only meet approximately.

12. It is important to use the centre pieces of the photographs and not the edges. The centre pieces are more accurate, as there is less distortion; and more clear, as photographically the best and sharpest part of the negative is that immediately above the lens.

13. This method of building up a strip of mosaic is much simpler to carry out in practice than to describe in writing. Once the method is grasped two men can mark, put together, and paste down a strip of twelve photographs in less than half an hour.

14. When the two photographs are overlapped, as in Sec. 100, it will often be found that they are slightly "staggered"; *i.e.* one is a little higher up or lower down than the other. If the photographs are then cut as described, a corner which is shown on one photograph, but not on the other may be lost. It is therefore better to cut round the corners in such a manner as to leave untouched any piece which is not common to both photographs.

15. The instructions given above apply to a single strip only. If it is desired to make a mosaic of a bigger area, it may be necessary to join two or more strips laterally. In flat country and given good flying, this should present little difficulty; the strips are placed so that corresponding detail overlaps, and are cut through and pasted down. When, however, the country is hilly or the photographs are at differing scales, it may be found that when the detail overlaps laterally at one end of a pair of strips, there will be a marked discrepancy at the other end. If so, it is better not to attempt to adjust the errors, but either to paste down and ignore the discrepancies, or to call in the assistance of technical troops.

16. If stereoscopic examination of the prints for relief or other purposes is to be made, it must of course be carried out before they are cut. The made-up strip can give no stereoscopic effect.

APPENDIX V

TABLES.

I. R.F. and Equivalent British and Metric Scales.

- II. British and Metrical Units of Length.
- III. Metric Squares Measures.

IV. Russian Metric and British Units of Length.

R.F.	Miles to	Inches to	Kms. to	Cms. to	R.F.	Miles to	Inches to	Kms. to	Cms. to
1 to	1 inch.	1 mile.	1 cm.	1 km.	1 to	1 inch.	1 mile.	1 cm.	1 km.
$\begin{array}{c} 5 \text{ M}, \\ 4 \text{ M}, \\ 3 \text{ M}, \\ 2 \text{ M}, \\ 1 \frac{1}{2} \text{ M}, \\ 500,000 \\ 400,000 \\ 316,800 \\ 253,400 \\ 255,000 \\ 250,000 \\ 250,000 \\ 250,000 \\ 260,000 \\ 126,700 \\ 126,700 \\ 125,000 \\$	$\begin{array}{c} 78 \cdot 91 \\ 63 \cdot 13 \\ 47 \cdot 35 \\ 31 \cdot 57 \\ 23 \cdot 67 \\ 15 \cdot 78 \\ 10 \\ 7 \cdot 891 \\ 6 \cdot 313 \\ 5 \\ 4 \cdot 735 \\ 4 \\ 3 \cdot 946 \\ 3 \cdot 157 \\ 3 \\ 2 \cdot 367 \\ 2 \\ 3 \cdot 157 \\ 3 \\ 2 \cdot 367 \\ 2 \\ 1 \cdot 973 \\ 1 \cdot 578 \\ 1 \cdot 263 \\ 1 \cdot 184 \end{array}$	$\begin{array}{r} -0127\\ -0158\\ -0211\\ -0317\\ -0422\\ -0634\\ -0845\\ -1\\ -1584\\ -2\\ -2112\\ -25\\ -2534\\ -3168\\ -3333\\ -4224\\ -55\\ -5069\\ -6336\\ -792\\ -8447\end{array}$	$\begin{array}{c} 50\\ 40\\ 30\\ 20\\ 15\\ 10\\ 7\cdot 5\\ 6\cdot 336\\ 5\\ 4\\ 3\cdot 168\\ 3\\ 2\cdot 534\\ 2\cdot 5\\ 2\\ 1\cdot 901\\ 1\cdot 5\\ 1\cdot 26\\ 1\cdot 26\\ 1\cdot 26\\ 1\\ \cdot 3\\ \cdot 75\end{array}$	$\begin{array}{c} 02\\ -025\\ -0333\\ -0667\\ -1\\ -1333\\ -1678\\ -2\\ -25\\ -3157\\ -3333\\ -3946\\ -4\\ -5\\ -5261\\ -6667\\ -7891\\ -8\\ 1\\ 1\cdot 25\\ 1-333\\ \end{array}$	$\begin{array}{c} 63,360\\ 62,500\\ 50,000\\ 42,240\\ 40,000\\ 31,680\\ 30,000\\ 25,344\\ 25,000\\ 21,120\\ 20,000\\ 15,840\\ 15,000\\ 15,000\\ 15,000\\ 5,280\\ 5,000\\ 2,500\\ 1,760\\ 1,000\\ 5,000\\ 1,760\\ 1,000\\ 5,000\\ 2,500\\ 1,000\\ 1,000\\ 5,000\\ 1$	$\begin{array}{c} 1\\ -9864\\ -7891\\ -6607\\ -6313\\ -5\\ -4735\\ -4\\ -3333\\ -3167\\ -25\\ -2367\\ -2\\ -267\\ -2\\ -267\\ -2\\ -1667\\ -1678\\ -0833\\ -0789\\ -0355\\ -0273\\ -0158\\ -0273\\ -0079\\ \end{array}$	$\begin{array}{c} 1\\ 1 \\ 1 \\ 0 \\ 1 \\ 2 \\ 2 \\ 1 \\ 5 \\ 2 \\ 5 \\ 2 \\ 5 \\ 2 \\ 5 \\ 2 \\ 5 \\ 2 \\ 5 \\ 2 \\ 5 \\ 3 \\ 168 \\ 4 \\ 4 \\ 224 \\ 5 \\ 6 \\ 6 \\ 336 \\ 12 \\ 12 \\ 6 \\ 6 \\ 336 \\ 126 \\ 72 \\ 3 \\ 6 \\ 336 \\ 126 \\ 72 \\ 12 \\ 6 \\ 72 \\ 12 \\ 6 \\ 72 \\ 12 \\ 12 \\ 6 \\ 12 \\ 72 \\ 12 \\ 12 \\ 12 \\ 12 \\ 12 \\ 12$	-6336 -625 -5 -4224 -4 -3 -25 -2112 -25 -25 -2112 -2 -2 -1554 -15 -1267 -1056 -1 -0528 -05 -0176 -01 -005	$\begin{array}{c} 1.578\\ 1.6\\ 2\\ 2.367\\ 2.5\\ 3.157\\ 3.33\\ 3.946\\ 4\\ 4.735\\ 5\\ 6.313\\ 6.667\\ 7.891\\ 9.470\\ 10\\ 18.94\\ 20\\ 40\\ 56.82\\ 100\\ 56.82\\ 100\\ 50.920\\ 000 \end{array}$

TABLE I.-R.F. AND EQUIVALENT BRITISH AND METRIC SCALES

	Mile.	Statute Mile.	Kilometre.	Furiongs.	Chains.	Fathoms.	Metres.	Yards.	Feet.	Links.	Inches.	Centimetres.
	1	152	9 1.8554 1.6093 1	9-223 8 4-97 1	92·23 80 49·71 10 1	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		2,029·1 1,760 1,093·6 220 22	$\begin{array}{c} 6,087\cdot 2\\ 5,280\\ 3,280\cdot 8\\ 660\\ 66\end{array}$	$\begin{array}{ccccccc} 0.87\cdot 2 & 9.223 & 73.04\\ 0.280 & 8.000 & 63.36\\ 0.280\cdot 8 & 4.971 & 39.37\\ 0.660 & 1.000 & 7.92\\ 0.66 & 100 & 79 \end{array}$		$185,537 \\160,934 \\100,000 \\20,117 \\2,012$
	1 Se	a or	Nautical M	lile.		1	1.829 1		$ \begin{array}{c} 6 \\ 3.281 \\ 3 \\ 1 \end{array} $	917 4,971 4 <u>17</u> 1.515	$72 \\ 39.37 \\ 36 \\ 12 \\ 7.09$	183 100 91·44 30·48 20.12
Latitude.	Statute Mi	Cables.	Metres.	Feet.							102	2.54
0° 30° 60°	1.1451 1.1480 1.1538 1.1568	10 10 10 10	$\begin{array}{c} 1,842 \cdot 86 \\ 1,847 \cdot 53 \\ 1,856 \cdot 93 \\ 1,861 \cdot 66 \\ \end{array}$	6,046·13 6,061·45 6,092·30 6,107·82	• M i he dii	s the mean re are no fferences a	n value of a t precisely re negligible	Sea or Naut the same a for map pu	tical Mile. s those add rposes.	The lengths opted by the	of this mile Admiralty	e as given , but the

TABLE II .- BRITISH AND METRICAL UNITS OF LENGTH

CONVERSION TABLES

TABLE III.-METRIC SQUARE MEASURES

	Square yards.	Acres.
1 Centaire (1 square metre)	1.196	-
1 Are (100 square metres)	119.599	0.02471
1 Hectare (10,000 square metres)	11,959.923	$2 \cdot 471058$

TABLE IV.-RUSSIAN METRIC AND BRITISH UNITS OF LENGTH

Statute Mile.	Verst.	Kilometre.	Sajenyam.	Metres.	Yards.	Feet (Futam).	Inches (Dyuimam).	Centimetres.
1	1·5086 1	1.6093 1.0668 1	$754.29 \\ 500 \\ 468.7 \\ 1$	1,609·3 1,066·80 1,000 2·1336	1,760 1,166·67 1,093·6 2·333	5,280 3,500 3,280·8 7	63,360 42,000 39,370 84	160,934 106,680 100,000 213-36

OTHER RUSSIAN MEASURES

1 Marine Sa	ajen	 	 =	l fathom
1 Arshin		 	 -	28 inches
1 Stopa		 	 -	14 inches
1 Vershok		 	 -	12 inches
1 Paletz		 	 -	1 inch

The Russian foot and inch are the exact equivalents of the British units.

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Printed under the authority of His MAJESTY'S STATIONERY OFFICE by William Clowes and Sons, Ltd., London and Beccles.

(6025) Wt. 3515-8707/216. 80m. 5/29. W. C. & S., Ltd. Gp. 310.





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