# MAPS
## A GUIDE TO
## PRACTICAL
## GEOGRAPHY

By the same author

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# MAPS

## A GUIDE TO PRACTICAL GEOGRAPHY

*by*

R. N. DUBEY, M.A., D. LITT.

*Head of the Deptt. of Geography, Allahabad University*

KITAB MAHAL ALLAHABAD

# PREFACE TO FOURTH EDITION

My experience of teaching Geography at this University leads me to believe that there is nothing that scares the Indian students more than the practical map work. I am convinced that this is due not to any inherent shortcoming in the student himself, but simply to the wrong approach to the subject at the earlier stage of the study. The map is looked upon not as a vehicle for conveying information, but as a piece of cartographic achievement. I am sure that any one who has a clear concept of the meaning of Geography will agree with me that cartographic art lies outside the domain of Geography in the same way as Mathematics, Physics or Economics even though we make use of the discoveries of these sciences. Steers in his 'Study of Map Projections' quotes a famous French Geographer, Camille Vallaux, as saying "La carte est le document de base indispensable pour la Geographie, et ce ne sont pas des geographes qui la dressent." (The map is an indispensable basic document for Geography, but it is not the geographer who constructs it.) This quotation defines the scope of practical map work, which should be centred on map reading. Success in map reading, however, depends on a thorough grasp of the principles of map making. It is only thus that the student can realise the limitations of maps. But the student should never forget that the fundamental object of his study is map reading, not map making.

Map Projections are an essential part of map making. But a geographer has never to draw them to produce his maps or to read those produced by others. He only makes use of outlines that have already been drawn by expert cartographers. Even when he draws the outlines himself, as in field-sketching, the area covered is so small that it is immaterial as to what projection is used. Yet he needs to know the properties of the map projection used in making the outlines of his map. Without this he cannot read the

map correctly. But to know these properties it is not necessary for him to enter into mathematics. He need not trouble himself as to how certain formula used in map projection have been derived. For this reason the subject of map projections has been placed at the end in this book. Only the most commonly used projections have been included.

The book is primarily written for Indian students and, therefore, the illustrative material has been selected from Indian conditions with which they are familiar.

The value of practical work in Geography is now being realised in India. Advantage has, therefore, been taken of the opportunity to revise it thoroughly. New material has been added where necessary, and new blocks and tables have been given to increase the usefulness of the book to the Indian student.

*University of Allahabad.*           R. DUBEY
    19-7-1952.

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# INTRODUCTION

A map may be defined as a conventional representation of the earth, or any part of it, as looked at from above, on a *flat* piece of paper. The representation bears a certain proportion to the area represented. This proportion is the *scale* of the map and is always marked on it.

There are four essential points in the definition of a map. The first point is that it is a *conventional representation* which uses conventional signs for various objects shown on the map. There are particular signs, say for railways, bridges, or roads or trees. These and only these signs must be used in a map to show the objects mentioned. These conventional signs have now been accepted all over the world. The significance of this fact is that a map that does not make use of these conventional signs cannot be called a "geographic map"; it may be described as a "sketch".

The second point is that the objects that are shown on a map are shown as they would appear if they were *seen from above*. Objects looked at from above, say from an aeroplane, appear flat. The buildings, the trees, and other objects are therefore shown as having only length and breadth, no height. The map has therefore only two dimensions, not three. The map is only a two-dimensional representation of the earth's surface. If three dimensions of the objects are shown, it becomes a "picture", or a "model", not a "geographic map."

The third point is that a map must be drawn on a *flat surface*. It is therefore to be distinguished from a globe which is drawn on a round surface. A flat surface can be easily folded up and can thus be stored or transported conveniently. A flat surface can also give an unobstructed view over a large area of the map, which is not possible on the globe. The flat surface of the "geographic map" therefore helps in the use of the map.

The fourth point is that a map is drawn to a *scale*. It has a fixed ratio of length and breadth to the length and breadth of the earth's surface that is represented on it. Without a scale you may have only a "sketch" not a geographic map. The scale implies that the lines of latitude and longitude drawn on the map are according to a particular type of "map projection". There can therefore be no map without a map projection.

The mere fact that the earth is round, while its representation is flat which cannot show the earth's curvature, implies that the very basis of all maps is wrong. The absence of a proper appreciation of this error has resulted in the past in our having in mind a wrong picture of the earth. We must remember that only the globe gives us a true picture of the shape of our earth.

The earth is, however, vast. Its surface is greatly varied and full of a variety of details. To take note of all this detail through the printed word in books is not practical. Consider how many pages will be filled if you listed only the moderate-sized towns of the world. You cannot look at all this list at one glance. You will have to spend some minutes before you have read though the whole list. Besides, the towns in your list give you nothing but their bare names. The list cannot give you any idea as to the setting and environment of these towns. It tells you nothing as to the relationship that may be existing between some of the listed towns.

Now, consider the case of all these towns being shown on a flat map which starts from a wrong basis of showing a round earth on a flat paper. In spite of its drawback, you can get a generalised picture of all these towns at one glance, in a few seconds. You can know at once in which part of the earth are there many towns, and in which part few. You can also note at the same time the topographical setting and the relationship of these towns. In short, the map enables you to grasp, at one glance, simultaneously divers details which it is not possible for you to do by any other method. The map therefore became, from the start, the chief instrument of the study of Geo-

graphy. For, it must be remembered, that Geography draws its conclusions about distributions only by considering varied details presented side by side. Not only do the maps present varied data side by side, in their proper relationships of distribution, they also help to fix these data more easily in the mind, for they are a kind of picture-reading which is less taxing to the brain than word-reading.

Although some kinds of sketches, made either on cloth or clay, were in use even in ancient times, for such have been discovered in Palestine and in Greece it must be realised that their geographic value must have been little when compared with the modern maps. The voyages of discovery, the increasing trade with the east, the invention of printing, and cartographical improvements; all led to the modern geographic map which has come to fill a real need in the life of the civilised world.

"A map is, however, only a means towards an end. Its purpose is to assist man in coping with his environment. In the compilation of the map therefore the aim should be primarily to provide for the reading of it by the synthetic method, in so far as the actual physiognomy of the globe is represented. It should present in the most readily understandable form certain groups of facts and relationships from which its user can deduce conclusions pertinent to the subject of his study."[*]

### MAPS AS "SECOND SIGHTS"

Maps really lift us far above the ground than any aeroplane can do. They give us a "second sight" for use in navigation of ships, or cars, or aeroplanes, in planning cities, or roads, or railways. Without the help of maps, the modern man would be groping in the dark. Maps not only interpret to us our environment, but are indispensable to our material progress. They show where things are. By knowing where things are, we can deduce where some things can be and where they cannot be.

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[*]Translation. Camille : *Journal de Géographie*, 1920.

## TYPES OF MAPS

Maps are of numerous types. Some are for *general use*, *e.g.*, maps of areas giving data of different kinds. Others are for *special use*, giving data of a particular kinds. The example of the latter is the climatic or other distribution maps. Cartographers are generally interested in the first type of maps.

Based on the size of their scale, the general maps are divided into the following types :—

1. *Cadastral maps*, drawn on a very large scale varying from 6 inches to 25 inches or more to a mile, are used to show estates or towns where the area to be represented can be conveniently covered by one sheet of paper.

2. *Topographical maps*, drawn on a fairly large scale, say from a quarter inch to 4 inches to a mile, represent small areas and give a large amount of detail of a varied nature.

3. *Chorographical maps*, drawn on a small scale, say 32 miles or 64 miles to an inch, represent large units of the world and give the most generalised picture of the area. These are generally the small scale atlas maps of countries. They are also called "atlas maps "

4. *World maps*, drawn on flat paper to take the place of the globe.

The last two types of maps, the chorographical and the world maps, were in existence even in early times. But the topographical maps are a product of the modern times. These maps are prepared after a careful survey based on triangulation. Modern Europe emerged from a number of wars during the 18th and 19th centuries which required for their success in operations topographical maps giving accurate information National surveys were therefore started by the countries of Europe from 1750 onwards.

France was the leader in these surveys. It was in that country that topographical maps based on accurate

triangulation were made and published first. Cæsar Francois Cassini (1714-1784), a de cendant of a famous family of cartographers of France, was the first to do this work. He started the 'Carte Geometrique de la France', in 1747 on a scale of 1/86,400 which was completed after his death by his son in 1789.

The Carte Geometrique was later followed by another series of topographical maps, Carte d'Etat Major on the scale of 1/256,000 prepared by Napoleon's engineers. In this series were included, besides France, parts of Italy, Germany and Austria.

Great Britain was not far behind France in topographical mapping. Ordnance Survey was founded in 1791 and triangulation was begun by General Roy. The first topographical map of Great Britain was published on a scale of 1/63,360 in 1801.

The Geographical Section of the General Staff (G. S. G. S.) of the British Army has produced topographical maps of areas outside Great Br tain, as well. Among these the maps of Asia and Africa are of special note.

Under an impetus from t e British army the Survey of India was started about the beginning of the last century to produce topographical maps of India. The survey has produced maps not only of India, but also of the adjacent countries.

The topographical maps that were produced by the different countries of the world followed their own scheme and scales, so that there was no co-ordination of any kind. The need for a common scheme and a common scale was therefore greatly felt. An event of great cartographical importance therefore took place when the International Geographical Congress of 1891, held at Berne, dicided in favour of such an international topographical map of the world on a scale of 1/1,000,000 (known as the 'millionth map'). Little was, however, done until 1909 when the British Government called a meeting of the principal governments of the world. A common scheme was decided upon and every Government was allotted a particular

area which it was to map. India and Great Britain are the only countries which have completed their allotted task. The 1/M map produced by the Survey of India is known as the 'India and Adjacent Countries' series. The sheets in this series are 4 × 4 degrees and have contour lines, altitude tints and shading.

The other countries are making this map in sheets as given below :—

Up to 60° and latitude the separate sheets are to include 4° of latitude and 6° of longitude.

Beyond 6° up to the pole the sheets are of 12° longitude and 4° latitude; *i. e.* two sheets of the above size are to be united into one.

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# MAP MAKING

As the map is a conventional representation of the earth, it is implied that the person who draws it must have *seen* the earth or *guessed* rightly what it looks like. In other words, the data for the map must be collected by *survey* or *interpolation* Surveying and interpolation are therefore the first steps in making a map.

## FIELD SURVEY

Surveying consists in determining the relative *positions* of the various objects on the ground, so that they can be shown on the map in the same relationship. In order to fix this relative position of objects, it is necessary to take some measurements. These measurements are of the *directions* in which the objects are situated and the *distances* at which they are situated from one another. No survey is useful unless both these measurements are carried out. Measurement is therefore the essence of field survey. The greater is the care taken in measurements, the more accurate is the survey. A careful measurement, however, takes time and requires much labour. This will entail a much greater cost than if less time is given to measurements and survey. In actual practice it is noticed that maps are required for various purposes. Some purposes require very elaborate and carefully-prepared maps. In such cases the survey has to be very carefully done. There are, however, other purposes for which even less carefully prepared maps will do. In such cases, a very careful and accurate survey, costing much money, is a sheer waste and uneconomical.

Survey work is therefore classified under two heads:—

(i) Traversing or a less careful work ; and

(ii) Triangulation, or an elaborate work.

### TRAVERSING

Traversing consists in surveying quickly a narrow strip along a road or a route, observing only the most prominent objects visible clearly from the road or the route followed by the surveyor. In some cases it is practicable only to make a few notes of the observations outdoor by the surveyor. Traversing with the help of a measuring tape or chain is also done to fix the boundaries of an estate In this case the surveyor walks round the property taking measurements. The notes are made in a note-book, called the field-book. Plottings are made later from these notes. The field-book is ruled according to the requirements of each surveyor, but generally it has a central column in which the data concerning the actual route or the path followed are given. To the right and to the left of this column the data are given concerning objects situated to the right or the left of the path respectively. The data in the central column consists of the measurements of :—

(i) *Direction.* The direction of the most prominent object which lies on the path ahead of the surveyor is measured by the compass and entered in the field-book. The measurement of this direction is expressed as a 'BEARING'.* This bearing is given in degrees of angle read from the dial when the compass is sighted on that distant point.

The dial of the compass is divided into 360 degrees in which North is placed at 360° (which is also called o), East at 90°, South at 180°, and West at 270°. The bearings are read clockwise and are given in degrees which may range from o to 359. The measurements obtained for the object looked at ahead on the path of the traverse is known as "Forward Bearing". Sometimes the surveyor directs his compass from his second station to the objects

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*The bearing is that angle which is made between the line of sight of the object and the magnetic N S. Line. The angle between the sight line and the Geographical North Pole line is known as the angle.

from which he had taken the "forward bearing". The measurement that is so obtained on the dial of the compass is known as "Back Bearing". This bearing is simply the difference between 360 and the figure obtained for "Forward Bearing". Forward Bearing plus Back Bearing are equal to 360 degrees. The Back Bearing is seldom recorded.

Direction measurements are taken not only of the objects on the path of the traverse, but also of the prominent objects lying to the right or the left of the traverse. These are noted down in the field-book along a short line drawn in the appropriate direction to the right or the left of the path where the object lies.

> (ii) *Distance.* The distances between the various intermediate points, as also the total distance between the starting point and the last point sighted from there are given. The total distance is written vertically in order to distinguish it from the intermediate distances.

As the surveyor moves along, he makes observations about objects to the right or the left of the path. These are entered on the appropriate side of the central column in the field-book. Such observations give :—

> (i) Offset distances to nearby prominent objects. The offset distances are always measured from a point on the path just opposite, *i.e.*, at right angles, to that object. It is not necessary therefore to take a bearing for that object.

> (ii) Bearings of objects which are situated at some distance which cannot be measured easily.

Besides the data mentioned above, names and any additional useful information about the objects observed are also noted at the appropriate place in the field-book.

Fig. 1 shows the specimen of a field-book.

Note that the entries in the field-book are made from the bottom of the page upward and from the last page backward. That is to say, if there are ten pages in the field-book, the first entry will be made at the bottom of

the tenth page and when that page is filled the next entry will be made at the bottom of the 9th page and so on.
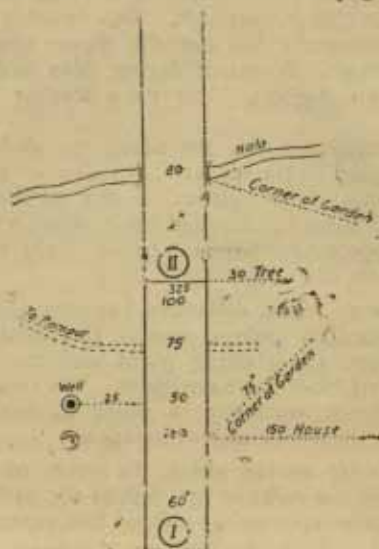


Fig. 1.

The stations are marked in their serial order and put in a circle. The distance separating one station from the other is called a *leg of the traverse*.

Conventional signs are often used to mark the objects observed.

Traverses are classified as :—

    (i) Open traverse, or
    (ii) Closed traverse

Closed traverse is that in which the survey ends at the starting point of the traverse. In the open traverse, however, the survey ends at a point far away from the starting point. Because of this, there is generally no possibility of checking the accuracy of the measurements taken

during the course of the open traverse. In the closed traverse, however, the error is invariably detected at the time of plotting, as the first and the last points do not coincide, which they should. The error is therefore distributed. If, however, the difference is very wide, a fresh traverse is undertaken.

The data in the field-book are later plotted on a paper. The plottings are done with the help of a protractor for measuring the angles and a ruler for drawing the lines. Before plotting, a suitable scale is selected for the distances. Then a north-south line is drawn on the paper on which the map is to be drawn.

Any point on this paper is selected as the starting point. At this starting point a line representing the magnetic north-south line is then drawn. With this north-south line the first angle representing the first "Forward Bearing" in the field-book is measured. The angles are measured clockwise, *i. e.*, in the direction in which the hands of a clock move. With this angle a line is drawn towards the second point of the traverse. On this line the distances are marked and the positions of the second point and other objects on the traverse are marked.

When the second point has been fixed, the plotting of the second "leg" of the traverse begins. A line is drawn at this point parallel to the magnetic north-south line drawn at the starting point. Then as in the first case, the angle of the Forward Bearing from the second point is measured clockwise. Another line is drawn towards the third point which is then fixed by measuring out the proper length of the second leg according to the scale selected.

The process is repeated until all the data have been plotted. The map is then ready for correcting any errors. After the errors have been eliminated, the map is ready for the cartographer who will finish it and send it to the press. That is how we get most of our maps.

### ADJUSTMENT OF ERROR

Plotting often reveals that the observations of bearings given in the field-book have not been correctly made.

This is found out by the last plotted point not tallying with the actual position of the object in the field. Where
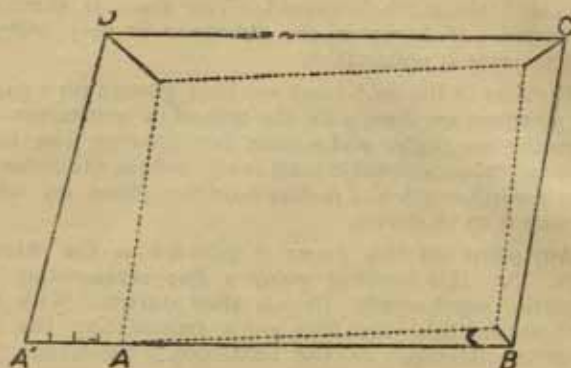


Fig. 2.

the exact position of the last object is known, the error is distributed and dotted lines are drawn alongside the original lines to show the correct path of the traverse. Where the traverse is *closed traverse*; that is to say, where the surveyor comes back to the same point from which he started, this error can be easily determined; for in such a case the last plotted point must coincide with the first point. In Fig. 2, the simplest method of adjusting such an error is shown.

The traverse started from A (Fig. 2) and finished there. In plotting also therefore A and A should coincide. The plotting, however, results in the figure ABCDA. That is to say, A and A' are not coinciding. To adjust this error A is joined to A' and the line AA' is divided into four equal parts, as there are four legs to the traverse. A small diagonal line is drawn to the left of B, C, and D in such a way that at B it is equal to one part, at C to two parts and at D to three parts. A dotted line then joins these new positions of the points B, C and D represented at the

end of the diagonals. The figure given by the dotted line shows the correct traverse.

Here is another field-book of a closed traverse :—

| |
|---|
| 600 yds. |
| 325° |
| E |
| 800 yds. |
| 220° |
| D |
| 450 yds. |
| 145° |
| C |
| 700 |
| 96° |
| B |
| 600 yds. |
| 8° |
| A |

We select a scale of 6″ to a mile for plotting it. We select point A as the starting point (Fig. 4). At this point we draw, with the help of a compass, the north-south magnetic line, which is shown here as a dotted line. With this dotted line we measure an angle of 8° with the protractor. We then draw a straight line AB and measure out 600 yards on this line according to the scale selected to fix the position of B. At B we draw a dotted line which is parallel to the magnetic north-south line drawn at A. With this line we measure an angle of 96°, and then draw another line BC. From BC we cut out 700 yards on the scale selected and fix the position of C. We repeat the process until the last bearing is plotted.

We find that the plotted traverse does not close. Points A and A′ do not coincide. Obviously, there is some error. To eliminate that error and close the traverse we adopt the following method :—

Join A and A'. This line gives the direction in which all the points must be shifted to get the traverse to close. Then total the lengths of all the legs of the traverse as given in the field-book. It comes to 3150 yards. Draw another straight line $A_1 A_5$ (Fig. 3) to represent this total distance on half the scale given for the
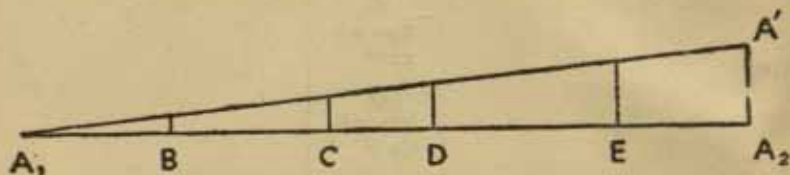


Fig. 3.
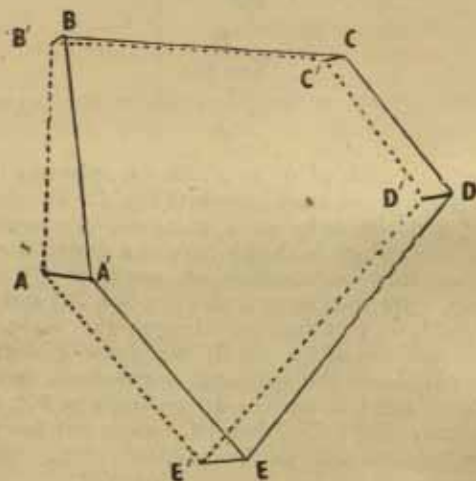


Fig. 4.

traverse, *i. e.*, 3 inches to the mile. (Any convenient scale that will suit the size of the paper may be selected.) At

$A_2$ A on this straight line draw a perpendicular $A_2$ A' equal to the difference between the starting point A and the closing point A' in the plotted traverse. Join $A_1$ and A' on this new line. Then cut out from $A_1$ $A_2$ the various legs of the traverse on the scale selected for this line. From each of the points B, C, D, and E drop perpendiculars to meet A, A'. Now, these perpendiculars are the distances by which the B', C'. D', etc., have to be shifted. The shifts are to be in the direction corresponding to the line joining A and A' in the traverse. The shifted points B' C' D' and E' are now joined by dotted lines which give the new and correct position of the closed traverse.
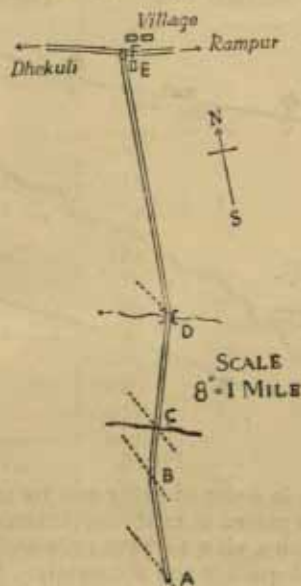


Fig. 5.

We shall now take an example of an open traverse.

The following field-book gives the necessary details for plotting.

### PLOTTINGS IN THE FIELD

Sometimes no field-book is prepared, but the observations are plotted, directly as they are taken, on the paper. This gives more satisfactory results. The survey by Plane Table is of this type.

### CHAIN TRAVERSE

The chain traverse is the simplest traverse and often consists of closed traverse. The chain is held on the ground in a straight line near the boundary of the field. Offsets are measured from this line, before removing the chain,
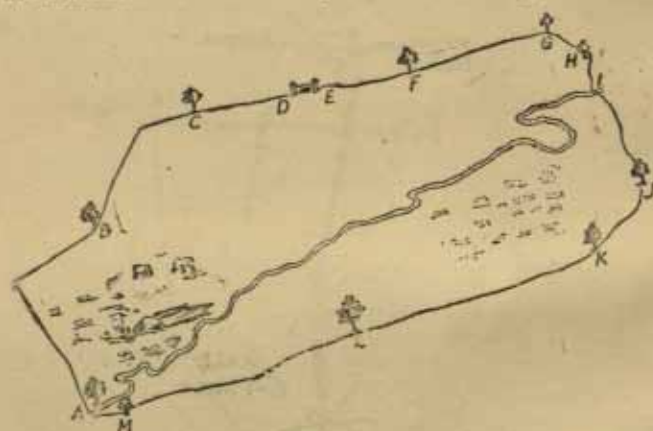


Fig. 6.

to the boundary in order to bring out its real shape. The chain should be placed as near the boundary as possible. This is done with a view to have only short offsets which can be measured quickly and accurately. Long offsets are always inconvenient for this purpose. While laying the chain on the ground, it is necessary to guide the man carrying the other end of the chain, so that he remains as near as possible, in a straight line close to the boundary.

The measurements are recorded in a field-book from which plottings are later made. The field-book is almost similar to the one used in a compass traverse.

Suppose we have to make a chain traverse of the field shown in Fig. 6.

We go round the field once and observe the prominent features that we shall use as ruling points. The nala, the trees and the gate are the most prominent objects for this purpose.

We start from the tree marked A on the nala. We lay the chain on the ground along the boundary in a straight line. We mark the position of the starting point by a

| Offsets | Links | Stations |
|---|---|---|
| | 600 | M |
| 10...... | 570 | |
| | 500 | L |
| | 400 | K |
| | 370 | J |
| 5...... | 350 | |
| | 300 | I |
| | 290 | H |
| 10...... | 280 | |
| | 270 | G |
| | 250 | F |
| 10...... | 220 | |
| | 200 | E |
| | 180 | D |
| | 140 | C |
| 10......... | 120 | |
| 5...... | 90 | |
| | 70 | B |
| 15......... | 50 | |
| 5...... | 10 | |
| | 0 | A |

Fig. 7

nail and holding one end of the chain close to it direct the man holding the other end to move to his right or left

in order to be in a straight line from the starting point. He then marks the position of his end by another nail or peg. This peg will be next point from which the chain will be spread onward towards the point B. When the second peg has been struck we measure the offsets from the chain to the boundary. All these measurements are entered into the field-book which is as in Fig. 7.

The diagonals AC, AG and AJ may be measured separately to help in plotting. When plotted, the field will appear as follows:—
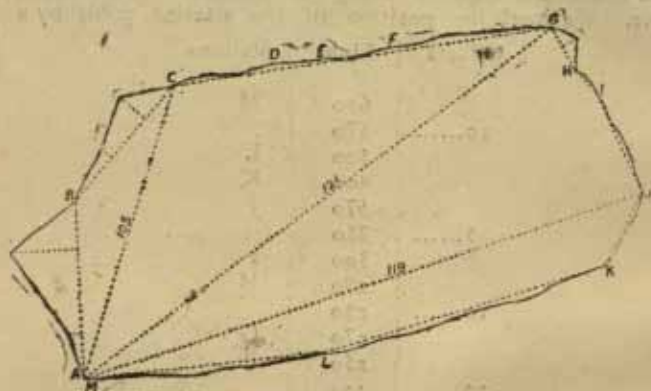


Fig. 8

The dotted lines in the above diagram show the chain lines while the regular line shows the boundary.

### INSTRUMENTS FOR TRAVERSE

All the usual instruments for survey, *e.g.*, the Prismatic Compass, the Plane Table, the Chain or the Theodolite can be used for traversing. The theodolite is, however, seldom used for this purpose, as it is comparatively unwieldy.

The most common instrument for traversing is the prismatic compass. It is an ordinary magnetic

compass provided with three special adjustments. These are:—

(1) A prism, to enable the reading of the bearing st raight without bending over the compass or shifting the position of the compass itself.

(2) A sight vane with a tin wire which is directed to the objects which are under observation.



Fig. 9

(3) A magnetic dial, instead of the usual needle. On this dial are engraved the graduated readings from o to 359. This dial moves to show the new bearing as soon as the compass is moved this way or that way.

For making observations the prismatic compass is :—

    (i) mounted on the tripod stand ;

    (ii) put in a level plane by adjusting the legs of the stand, so that the liquid in the spirit level fixed on the compass is in the middle ;

(iii) the prism and the sight vane lifted straight.

Now, stand on the side of the prism, put one finger on the stop-button under the sight vane, and look at the object through a small hole on the prism-side by fixing one eye to it while closing the other eye. You are looking now at the object through the sight vane and also at the graduated reading of the dial on the inner side of the compass under the sight vane. In order to get the bearing, you must steady the magnetic dial by pressing the stop-button just for a while.

The advantages of the prismatic compass for traversing are :—

1. It is portable and therefore can be easily taken from one place to the other, even in a difficult country.

2. It is suited for quick work, specially in a flat forested country where there are no prominent landmarks.

Its disadvantages for this work are :—

1. It is expensive, costing about two hundred rupees, especially when compared with the plane table which costs about fifty rupees only.

2. The accuracy of its observations is generally impaired due to the magnetic effect. The magnetic dial is attracted towards the magnetic objects and does not therefore give the correct bearing of the object sighted.

Because of this defect it cannot be used near iron. Bridges, railway lines, iron poles, etc., cannot be used therefore as observation points.

### PLANE TABLE

The Plane Table is a kind of ordinary drawing board mounted on a detachable tripod. It is fixed to the tripod by means of a screw on top. When this screw is tightened the table is fixed. To revolve the table, however, in any direction the screw is loosened. The size of the table varies, but usually it is small, about 10″ by 15″.

Besides the table top, there are two other accessories of the plane table which must be regarded as essential parts. These are the ALIDADE (it is also called the sight-rule), and the BOX COMPASS (also called Trough Compass). The alidade is a flat graduated ruler at the two



Fig. 10.

ends of which are fixed two sights. Sometimes these are flap sights which can be lowered flat on the ruler when out of use. One of the sights has holes, while the other has a long slit through which passes a hair or a thin wire. In order to use the alidade the surveyor puts his eye to the sight that has a hole and looks at the object through the slit in the other sight. It is necessary that the hair or the thin wire in the slit should be supposed to cut the

object sighted. In order that there should be no errors in sighting, the line joining the sights at the two ends of the ruler must pass through its centre. Sometimes, for very accurate work in place of the sights at the end of ruler, the alidade has a telescope mounted on its centre.

The box or trough compass is a rectangular box covered with a glass lid. It contains a magnetic needle moving on a pivot to show the magnetic north. The chief use of the box-compass is to draw two parallel north-south lines enclosing the box so that the table might be properly 'set' with their help at any place.

A tape for measuring distances and a spirit level for levelling the table are also necessary with the plane table.

## CHAIN

The chain (often called Gunter Chain) consists of 100 links or iron rings linked together. To facilitate countings, every tenth link is marked by a brass tag. The total length of the chain is twenty-two yards. Its use is confined to making boundary surveys of small fields.

## TRIANGULATION

The object of triangulation is *area-survey* rather than *route-survey*. For this purpose the field of operation is divided into a number of triangles. This gives the word 'triangulation'. The essence of triangulation lies in *measuring the base line of a triangle* and thus fixing two of the points of that triangle. The third point of the triangle is fixed by intersection of the *direction lines* drawn from the two ends of the baseline. It will be noted that the only measurement involved in this kind of survey is the measurement of the base. All other measurements are deduced by the simple rules of trigonometry. As the points of the triangles are fixed by observation from two points they are accurately fixed. Thus, less measuring and greater accuracy are the outstanding features of surveying by triangulation. This method of surveying, however, implies a more detailed observation and therefore it is necessarily slow. In military parlance triangulation is called 'position-sketching'.

Triangulation is of two kinds :—

    (a) Theodolite Triangulation ;

    (b) Graphic Triangulation, or the triangulation done with a plane table.

### THEODOLITE TRIANGULATION

The theodolite is an elaborate but very expensive instrument. Its chief feature is that it can measure more accurately the angles formed by objects sighted than is
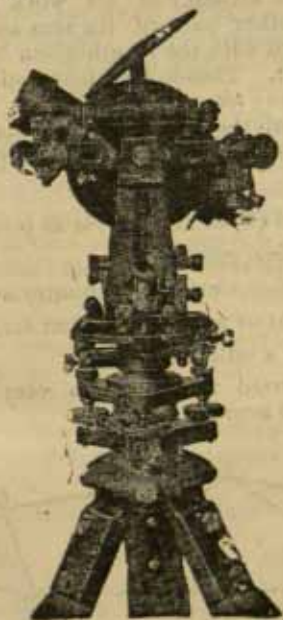


Fig. 11

possible with the help of a prismatic compass. Because of this accuracy larger areas are first divided into triangles with the help of the theodolite and the details within the

triangles so formed are later filled in with the help of the plane table. The points of these triangles are marked by permanent masonry structures and are known, as *trignometrical stations.*

Before an area is triangulated, a preliminary survey for ruling points is carried out. Then a base is fixed and triangulation proceeded with by forming new triangles from each of the points fixed. This process is continued until the whole of the area has been triangulated. In order to check the accuracy of the work a *check base* is measured in another part of the area and this measured length is compared with the length given by computation from the triangles. Theodolite triangulation, really speaking consists in *fixing the base, extending it and checking it.* This importance of the base requires that the surveyor should pay particular attention in selecting it. The baseline should :—

    (i) Be *central* to the area, as far as possible ;

    (ii) Be on a *level* ground.

    (iii) Give a *clear* view of the country around ;

    (iv) Give sight of a few prominent *landmarks* ;

    (v) Be about a mile in length.

    (vi) Be measured several times very carefully and then the average taken.
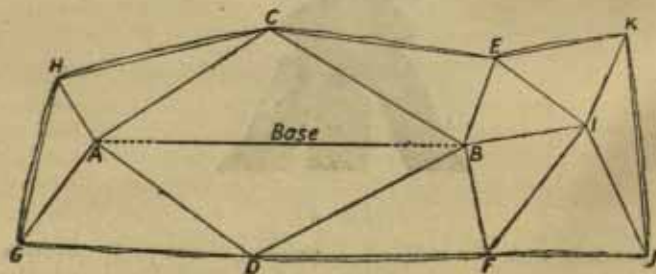


Fig. 12

Similar care should be given to the selection of the ruling points. These points should be so selected that the angles formed by them with the baseline should be as near right angles as practicable. Objects forming too obtuse or too acute angles should be avoided. Theodolite triangulation is shown below :—

In the figure above A, B, C, etc., are the points of the triangles fixed by triangulation. The dotted line shows the extension of the baseline.

The preliminary survey of the area leads the surveyor to select the prominent objects marked by the letters A, B, C, D, etc. The base is then selected and measured. With the help of the theodolite it is then extended to A and B which are objects situated several miles apart in the same straight line. From A the theodolite is sighted on B and then at C and the readings noted. These readings determine the angle CAB. The theodolite is then taken to B. From there it is sighted on A and C respectively and the angle ABC is thus fixed. Then it is shifted to C and by the same process the angle ACB is fixed. The side CA is now taken as a base and the point H is fixed. Similarly the side CB is considered as a base for fixing E. By continuing this process of taking the sides of the already fixed triangles as base new triangles are fixed. The triangulation is thus completed.

When the details are filled in by the plane tabler, these points are used by him, and it is not necessary for him to measure a baseline.

### GRAPHIC TRIANGULATION

When the plane table is used to make a framework of the area as well as to fill the detail of the area surveyed, the survey is described as 'graphic triangulation'. In such a case the first thing is to fix carefully a baseline. All the points given in connection with the baseline under theodolite triangulation apply to the baseline in graphic triangulation as well. In length, however, it is shorter in order to suit the convenience of the plane tabler. Once the baseline has been fixed the other points are easily

located. One special advantage of surveying by the plane table is that once the table has been set, the directions are measured easily and accurately merely by aligning the alidade on the ruling points. As in the case of the theodolite triangulation, points already fixed help the fixing of other points. It has been noted above that in the theodolite triangulation the baseline is measured and then the angles are measured. In graphic triangulation, however, the only measurement involved is the measurement of the baseline. All other measurements can be found out by computation.

The process of graphic triangulation implies first the mounting of the paper on the table. For it must be remembered that all plottings in graphic triangulation are done directly from observations in the field. The paper should therefore be fixed in such a way that it does not move, even slightly during the course of operations. The best method of fixing the paper is to pin its edges under the top of of the table so that there are no pin-heads on the table-top to obstruct the free movement of the alidade. A more satisfactory method is to wet a piece of thin cloth and place it on the table, smoothing the creases. On top of this cloth the paper is then placed. The edges are, as before, pinned under the top. This method gives a smoother surface of the paper and the drawing of lines becomes very easy.

To start operation, first select the two conspicuous points which will form the ends of the baseline. Place the table near one end of the baseline and then level it, that is to say, place its top in a horizontal plane. For this purpose help is often taken from a spirit level. Draw the north line with the help of the compass. When the table has been put in a level and the North line drawn it is said to be 'set'.

Now, mark a point on the paper to represent the position of the table. Put this point in a circle so that it is not lost. Then loosen the screw holding the table-top on the stand. This is called 'unclamping' the table. Place the alidade alongside the point and revolve the table

until the object at the other end of the base can be sighted through the sight vane of the alidade. Now tighten the screw under the table top. This is called 'clamping' the table. Then draw a line along the edge of the alidade in the direction of the object sighted. This line is the BASE LINE. The line representing the 'Base' is usually a thick line.

Having drawn the Base Line, the alidade should be pointed to other prominent objects visible from the position of the table and *direction lines* drawn. These direction lines are called *'rays'*. For drawing the rays the alidade is pivoted at the point representing the end of the Base Line and shifted to the right or the left to bring it opposite to the object to be sighted. It must be remembered that throughout these operations the table remains fixed. It is only the alidade that is moved.

When the rays have been drawn from the first point of the Base to all the objects desired to be fixed, the table is shifted to the other end of the 'Base Line' carefully measuring the distance. Before doing this a peg is left at the first end to mark the position of the table.

At the other end of the Base Line the table is placed and the top put in level as before. It is then unclamped and revolved with the alidade lying alongside the Base Line already drawn. The alidade is pointed at the object at the first end of the Base. When this object has been got through the sight vane the table is clamped by tightening the screw. The table is now said to be ORIENTED. The orientation of the table, thus, means the placing of the table in such a way that the two objects marking the two ends of the Base are in one straight line.

When the table has been oriented, the length of the Base is marked on the Base Line by a point which fixes on paper the position of the second object. For this purpose a suitable scale for representing distances has to be adopted. The measurement of the Base and its representation, the Base Line, on paper should be very carefully done, as this will form the basis of all compu-

tations to be made for finding the distances between various objects in the field.

Rays are then drawn from the second point of the Base to all objects to which they were drawn from the first point. This is done on the same principle as in the
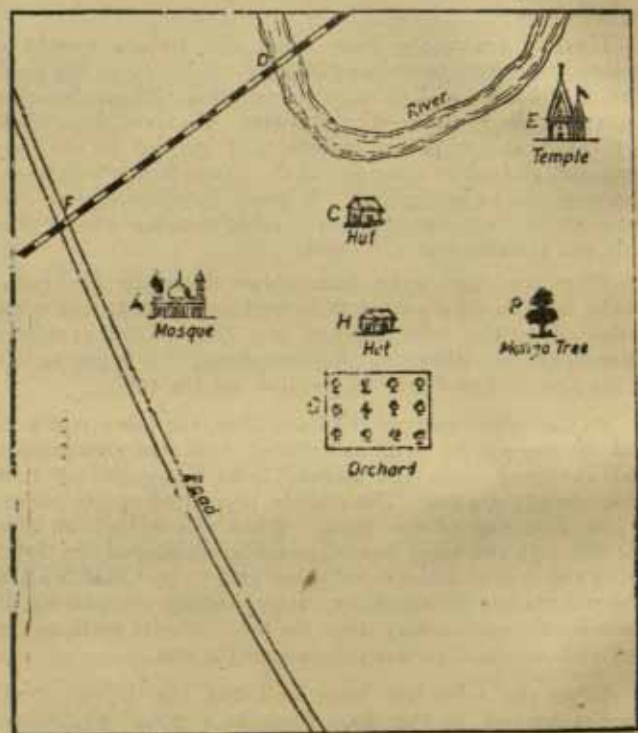


Fig. 13

case of the rays from the first point; *i.e.*, by pivoting the alidade on the point and moving it right or left to get the objects into the sight vane one by one. These second

rays will intersect the first rays at a certain point. This point of intersection fixes the position of the object sighted.

If necessary, rays to new objects not visible from the first point of the Base, may also be drawn. These rays may be utilised later from other points.

The framework is thus provided. Now, rub out all the unnecessary lines leaving only the Base Line and the intersections of rays. Topographical details may then be shown. Rivers, roads, trees, etc., may be sketched with the help of the positions of the objects already fixed in the framework. The figures given here (13,14 and 15) show how the paper on the table will look as the operations described above are completed.



Fig. 14

The above field (Fig. 13) is to be surveyed by Plane Table. A preliminary survey will reveal the various prominent features shown in the diagram. It is clear that the mosque and mango tree can very well form the two ends of the Base marked A and B. The table is placed near the mosque and a direction line is drawn towards the

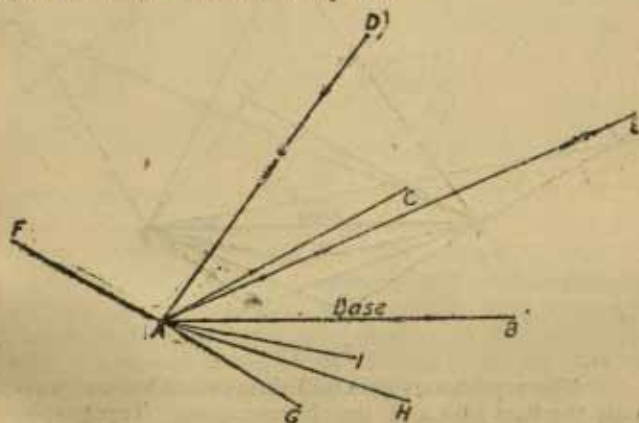mango tree. Rays from A are then drawn to the hut (C),
railway bridge on the river (D), Temple near the river (E),
Levell crossing (F), the corners of the orchard (G and H)
and other hut (I). These operations will appear on the
paper as below :—

The table will then be shifted to the mango tree
and oriented. The point B will then be fixed by plotting
the measurement of the distance between A and B. Rays
will then be drawn from B to all the objects to which they
were drawn from A. These operations will appear as
below :—
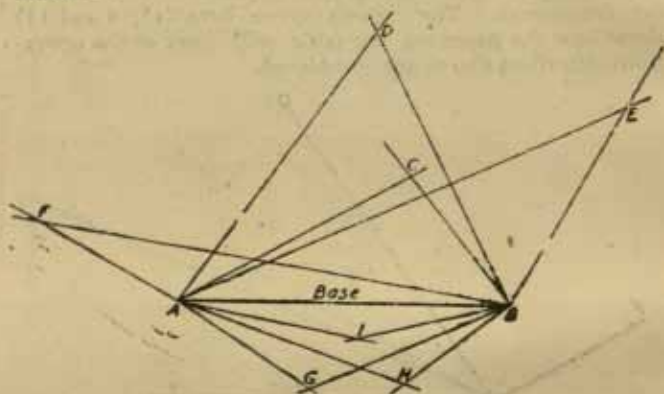


Fig. 15

The superfluous lines will then be rubbed out leaving
only the Base Line and the intersections. Topographical
details will then be sketched in.

### RESECTION

Resection is the method for determining one's posi-
tion on the Map. It describes the process of fixing the
position by referring to previously fixed points without
actually going to them. For this purpose the map is
placed on the top of a plane table and set. Some familiar
objects in the field which are shown in the map are then

sighted in such a way that the line of sight passes through the representations of those objects in the map. Rays are then drawn on the map backward from the object sighted to the position of the table. Where these rays intersect, that is the position of the table in the map. To get results it is better to select at least three objects situated in three different directions in the field.
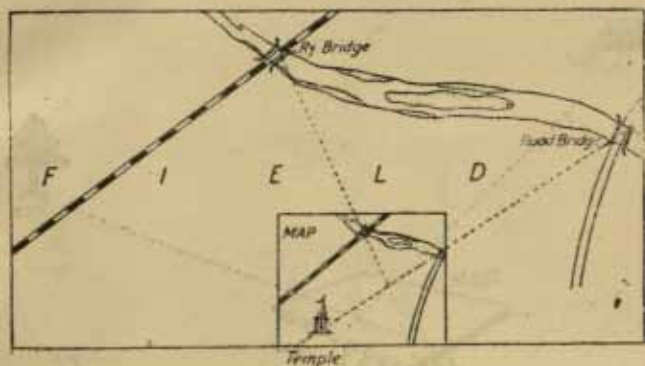


Fig. 16

Very often, due to defective laying of the table, the rays do not meet in one point. They form a triangle. This triangle is called the *'triangle of error'* (Fig. 17). The table has then to be shifted to the right or the left and the rays are drawn again before they intersect in a point.

The shifting of the table is done according to some rules. These rules are as follows :—

(i) If the table stands within the triangle made by the objects in the field, its position on the map will be *within* the triangle of error. If it stands outside, the position will be *outside* the triangle of error.

(ii) If the position is outside the triangle of error, it can only be either to the right or to the left of the triangle of error.

(iii) The position will be nearer to that side of the triangle of error which is formed by the shortest ray, and farthest from that made by the longest ray. In other words, the perpendicular lines drawn from the position to the rays bear the same proportion as the distance separating it from the objects. In short, shift towards the ray from the nearest object to the table.
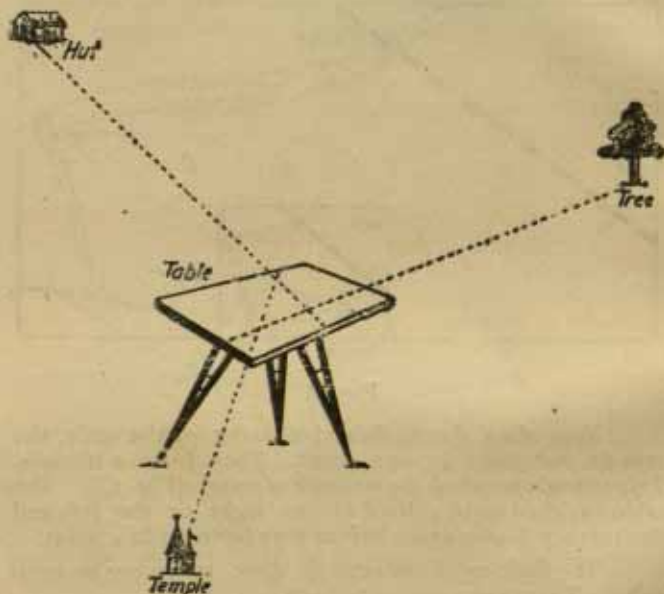


Fig. 17.

In order to decide whether the position is to the right or the left of the triangle of error, the table is to be shifted to the right or the left and rays drawn again. If the resulting triangle is smaller the position is to the side to which the table was shifted. If the triangle is larger, the position must be on the opposite side.

In Fig. 17 the position is within the triangle of error, while in Fig. 18 the position is outside that triangle.



Fig. 18.

Resection fails to fix the position of the table when it is on the circumference passing through the objects selected for drawing rays. Such objects should therefore be avoided, for they are in the 'danger circle.'

### TRACING PAPER METHOD

Position on the map is also sometimes determined by the tracing paper method. For this purpose take a piece of tracing paper, place it on the table and tack it. A point, say D, is selected in the centre of the tracing paper. Rays are then drawn from this point in the direction of three objects visible in the field. After this the tracing paper is untacked and is moved around over the map until these three rays pass through the three corresponding points for the objects on the map. There is only

3

one position of the tracing paper which will satisfy this condition, and the central point, D will thus give the position of the table on the map.

The table should be oriented then by placing the alidade on any one of the three rays and the corresponding object in the field sighted.

### CONTOURING

While the framework of an area is being completed with the help of a plane-table or a prismatic compass, heights of objects above sea level and the general slope of the ground are also marked in the map. This latter process is called 'Contouring.' For this purpose, a clear idea of the drainage lines and the main ridge lines is necessary.



Fig. 19

To facilitate contouring two things are essential in the framework being prepared. The first is the marking of the rivers, and the second, the location and the observation of elevation (known as spot height) of certain selected objects in the field. The marking of the river and the location of the object is done in the ordinary course of the survey. The observation of the spot height is done by various means. 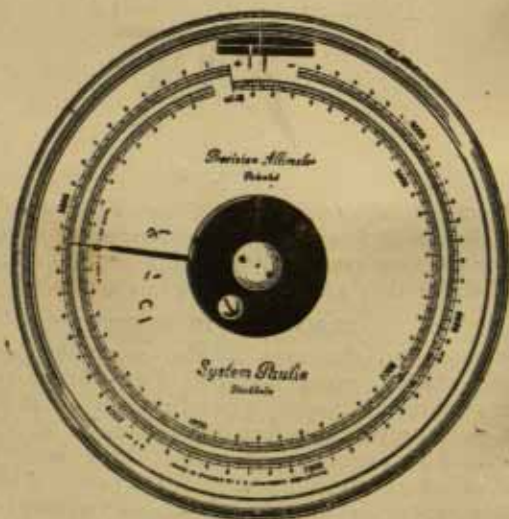If the surveyor is on the spot, *i. e.*, on the top of the elevation the height may be observed by the use of a barometer. The barometer records decreasing air pressure with increasing height above sea level. The normal air pressure at sea level being known, the height can be deduced by a simple arithmetical calculation.

The following gives the figures of a spring barometer or the 'aneroid' :—

The height is also found with the help of another instrument called the 'Level'. The Abney Level is in common use. The Level measures the vertical angle, and with the help of this angle and the horizontal distance separating the observer from the object the height is deduced.

The vertical angle can also be measured by another instrument called 'the Clinometer.' The Indian Clinometer is the cheapest and the most common in use.

From the spot heights and the general impression of the slope of the ground contours are interpolated. First of all the contour interval (or the V. I.) is decided upon. Then the places where the contours will cross the river are marked. To mark the places where the contours will cross the river, it is necessary to select a portion where the slope is uniform and the view unobstructed for some distance. The length of this stretch of the river is then estimated by the eye and divided by the contour interval. These divisions mark on the map the points where the contour lines will cross the river.

In the following plan (Fig. 20) the spot heights and the rivers in a certain area are shown and the contour lines are to be interpolated.

In the diagram A marks the lowest po'nt on the main river. B, another point situated on the same river, is separated from A by a uniform slope. If the contour interval of 50' is adopted, A and B will be the points through which the contour lines of 50' and 100' respectively will pass.
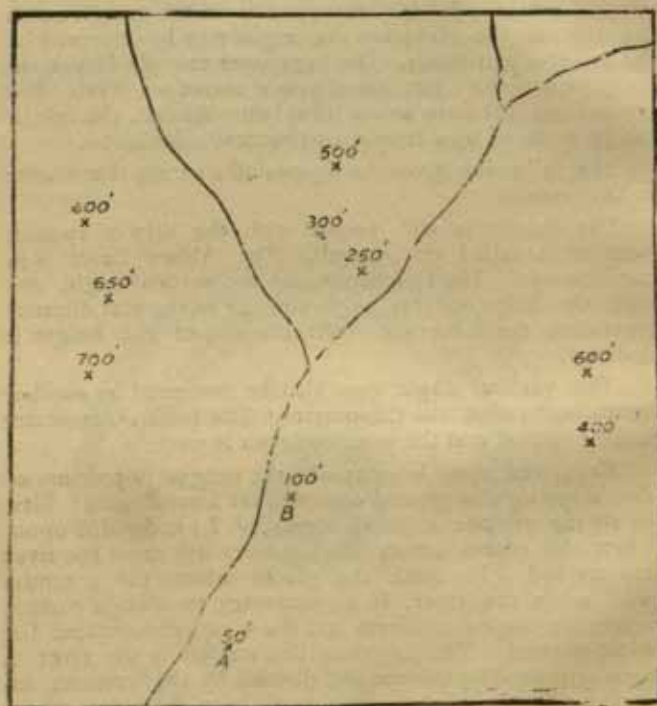


Fig. 20

The ground between the river forks is always a ridge. We notice from the heights given in the diagram (Fig. 20) that these ridges are provided here by the hilly ground to

the right and left of all the rivers in the upper course. The observer in the field will be able to notice the exact direction of the slope and the hills. It is necessary to remember in this connection that *contour lines bend upward in the river valleys and downward in spurs* or hill slopes.

The above sketch may therefore have the contours something like those given in Fig. 21 on p. 40.

While drawing the contours every fifth contour line is made thicker than the rest to facilitate reading. At the two ends, where they do not meet in the same map, or along the contour lines the height represented by them is indicated in figures.

Sometimes contours have to be drawn in the office away from the field of observations. The practice in such cases is to select the highest measurements first and connect them roughly by a contour line. We should then take the next lower heights until the whole data are finished. In drawing the contours in the office a good deal of interpolation becomes necessary, for the worker in the office does not have the advantage of observing the slopes actually in the field.

The following illustrates the method of interpolating the contour A look at the spot heights given will show that this is a valley trending towards the north. For the highest heights are at the southern margin, while towards the north they decrease. We should therefore interpolate the contours in such a way that a valley-form would result.

The second point to be noted is that the slope is gradual, as is shown by the fairly long distance separating the lower from the higher values of the spot heights.

We decide to have the contour interval of 100 feet. This means that we have to draw the contour lines for 500 feet, 600 feet, 700 feet and 800 feet. We start with the highest contours. We take first of all the distance between the spot heights of 620 feet and 730 feet. These heights are marked A and B respectively in the diagram. We find that this distance roughly marks the rise of 110

feet (difference between 620 and 730). Assuming that the same rise continues towards the contour of 800 feet, we shall have to fix that contour at about two-thirds this distance beyond B. The point B is about 70 feet below the contour of 800 feet. eW mark a point. Then we
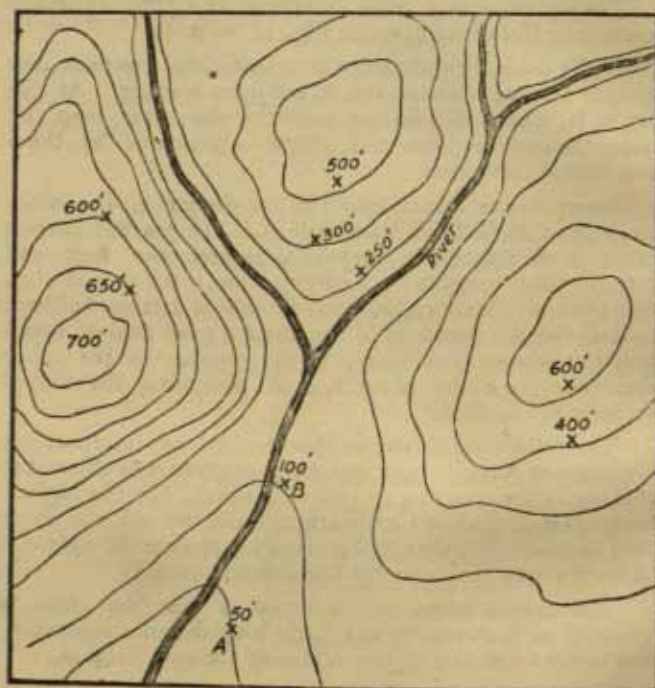


Fig. 21

pass on to the spot height of 720 marked C in the diagram. Here we notice that a rise of 80 feet ha : to b: provided for We consider the distance between the spot height of 680 marked D and 720 marked C. On that basis we fix

the next point through which the 800 feet contour will pass. We repeat the process until the contour is completed.

Then we take the next lower contour of 700 feet and follow the same process until all the points of this contour are fixed.

In this way, we have interpolated all the contours required.
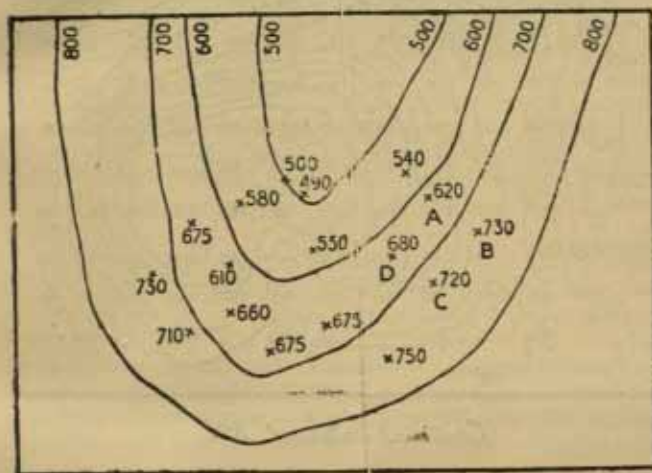


Fig. 22

We give in Fig. 23. another example of contour intrpolation.

In this case only the spot heights were noted. These spot heights must be very carefully studied before undertaking the interpolation of the contours. This study reveals that it is a very broken country, for the spot heights change frequently. Another point revealed is that there is a dissected plateau to the south-east. There are

hills to the north and another plateau to the west. The contours should be filled in to correspond with the shapes of the above-mentioned topography.
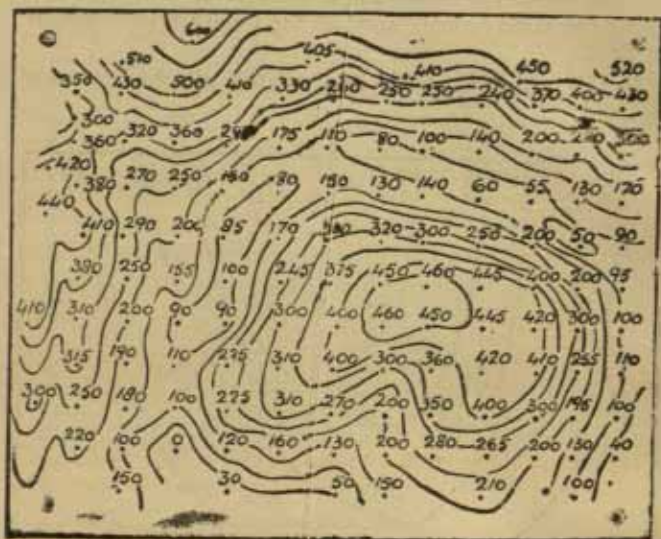


Contour Interval 50'

## MODERN METHODS IN MAP MAKING

It will be clear from the foregoing discussion that all the information that appears on maps is derived ultimately from observations in the field. The surveyors' task has been considerably lightened, however, in modern times. Certain modern inventions have been placed at his disposal which not only facilitate his task, but quicken it, too. There is the short-wave radio, for example. It keeps him in touch with the outer world, and enables him to determine longitude precisely from time signals broadcast

regularly from observatories. The aeroplane is another great help. The surface of the earth can be photographed from an aeroplane with special type of cameras. New techniques have been developed, called photogrammetry, for plotting information on maps from those photographs. Through these photographs, not only is the work of survey done very quickly but an abundance of precise detail that might never have been disclosed had the surveys been made on the ground by the traditional methods, is made available. The camera picks up many things hidden from the ground-surveyor. Oblique air photographs cover a much wider extent of the ground than would be possible by any other method. From these photographs small scale maps can be easily prepared. For large-scale maps, however, the oblique photographs are not suited. For large scale, vertical photographs are better suited. Surveying with the aid of photographs taken on the ground is still widely employed as an adjunct to the air photogrammetry.

### AIR SURVEY

Recently areas have been surveyed also by taking photographs from the air. These photographs are taken by special cameras in such a way that the areas covered by them overlap to the extent of 50 or 60 per cent. With the help of a stereoscope, these photographs supply details for maps in a laboratory.

The science of air survey is developing in India with notable success. More than 83,000 square miles have been surveyed here by air since the operations began in 1924. The air surveyor is saving both time and money needed, say, for example, in the revision of large scale agricultural and town maps, the planning of public works, the prevention of flood, or the prospecting for oil or other minerals.

Forestry and delta surveys first engaged the air surveyor's attention, because of the excessive cost of surveying such difficult terrain by normal means. The revision of large scale maps of, agricultural districts and town surveys were then taken.

Before 1928, little was known about Air Survey. Pioneering work was done in this respect in Burma, the Federated Malaya States and Borneo in compiling maps of forests, rivers, coast lines and deltas. The experience gained here was put to use in producing in 1927-28 as an experimental measure a map of the Chittagong district on the scale of 16 inches to the mile.

The technique of air survey was not sufficiently developed at that time, specially for producing a map on such a large scale. Due largely to the efforts of the Survey of India, however, new methods were developed and during the following years four complete districts of Bengal and 4,000 square miles in U. P. were mapped from the air.

Air photography is also being used for geological survey. Oil prospecting in Baluchistan was advanced by air photograpy when more than 1,000 square miles of land were surveyed. Important geological surveys have also been carried out in Bengal and Burma.

### DISTRIBUTION MAPS

Distribution maps differ from topographical maps in that they show some one characteristic of the area. The question of the exact *location* of any object or feature does not arise in such maps. It is the general *appearance given by the surface distribution* of something that is emphasised by these maps. This something may be a crop forests; some element of weather; like rain, heat or air pressure: or people. Topographical maps, on the other hand, try to locate almost every fixed object on the surface. Within the limits of the scale, *i. e.*, the size of the map, they include every fixed detail, of whatever type. In short, the distribution maps give the *areal distribution* of a certain element.

The distribution maps are classified broadly into two classes :—

> (i) Maps of qualitative areal distribution.
> (ii) Maps of quantitative areal distribution.

## QUALITATIVE MAPS

The maps of qualitative areal distribution are of two general types :—

(*a*) Maps of simple areal distribution. They show the area covered by a particular element. Thus, a map showing the area covered by forests, irrespective of the different types of forests found there, is a map of simple areal distribution.

(*b*) Maps of compound areal distribution. When a distribution map shows the different types of the same element, it is a map of compound areal distribution. Thus, a forest map which shows distinctly the distribution of the coniferous type of forest, the deciduous type of forest, and the evergreen type of forest belongs to this category.

The qualitative distribution of maps may be shown either by colouring the area or by making it with symbols or patterns. The colour method is called the *choromatic* method, while the symbol method is called the *choroschematic* method.

## QUANTITATIVE MAPS

A map sometimes shows the quantitative variation in the distribution of an element. There is a greater density in distribution in one section of the Map than in the other. To prepare these maps it is not enough to know where a certain thing is found, but *how much* of it is found. The basis of the quantitative map is supplied by the statistics issued by the governments or other recognised bodiies. Unlike the topographical map, the data for the quantitatve distribution map are collected by the statistician and not the mapmaker. The main purpose of the quantitative maps is to provide a visual help for statistical comparison of various areas. It is not the object of this type of map to be a source of statistical information about individual places or areas. This information is best supplied by the statistical reports themselves which are the basis of these maps. Its main object is the comparison of areas. This

map also shows the influence of geographical factors on the distribution of the particular element.

There are three main types of the quantitative distribution maps :—

(*a*) The isopleth maps,

(*b*) The dot maps, and,

(*c*) The choropleth maps.

### ISOPLETH MAPS

Isopleths are lines connecting places of equal density or value on a map. Such lines may be isotherms, which connect places of equal temperature, isobars (equal pressure), isohyets (equal rain), or isohypses (lines of equal height, *i. e.*, contours). The lines are drawn only for selected intervals, so that the map may not be overcrowded. For overcrowding in a map mars its value as a means of quick grasp.

The isopleths can be drawn only from accurate data, if they are to serve their purpose. They can be drawn only for areas where the distribution is fairly transitional, *i.e.*, where a certain gradation can be fixed. On the other hand they cannot be drawn for those elements whose distribution is too varied. For this reason isopleths cannot be used showing the distribution of crops. The distribution of crops is too variable.

### DOT MAPS

Where the distribution of elements is too varied or where there is no transition in it the variation in the distribution is shown by dots. A certain value is fixed for each dot and the dots to be represented are divided by this value to get the number of dots that will be placed on the map. The value of the dot to be fixed will depend upon the quantity to be represented and the scale of the map. For example, if the total output of wheat to be represented on a map is 25,00,000 mds. and the map is small, the value of the dot will have to be fixed high,

say 5,000 mds. This will give fewer dots which can be easily accommodated on a small map. If the map is a large one, the value of the dot will be fixed low, so that there will be many dots to fill the map.

While placing the dots on the map, the geographical conditions determining the distribution of the thing should be carefully considered. The dots should therefore be placed only in those parts of the map where the thing is expected to be. The dots representing the distribution of wheat should thus be placed where there are plains, not on hills. Besides every dot should be placed in the centre of gravity.

Sometimes, different shapes of the dots are used for showing the distribution of two or more different things. Thus, for example, round dots may be used for one thing and square dots for another. Dots of different sizes are also used sometimes for different units. Larger dots are then given a higher value than smaller dots. In short, the dot method can be easily adapted to different needs.

Where the intensity of distribution is the greatest, the dots should be combined to form a smudage or a blot.

### CHROPLETH MAPS

When lines or shadings are used to cover different areas of the map to give them different values, the map is called a choropleth map. Such maps show the ratios or percentage of certain distributions. In order to make the areas distinct, different kinds of lines or shadings are used.

### EXERCISES

1. What is map ? Describe how it is made.

2. Classify maps into important types.

3. Give a brief survey of the origin of topographical mapping.

4. What do you understand by triangulation ? Illustrate your answer by imaginary sketches.

5. What is a 'traverse' ? Explain the method of surveying by a traverse.

6. Explain, with the help of sketches, how you would carry out graphic triangulation with a plane table.

7. What is surveying ? Classify it according to its degree of accuracy.

8. What is a Field Book ? Make an imaginary Field Book and plot its data.

9. Explain, by means of sketches, how the error in traversing is adjusted in plotting.

10 Describe, with the help of sketches, how you would carry out a boundary survey of the field.

11. What is a 'triangle of error' ? Explain, by means of sketches, how you would demolish it.

12. Describe the tracing paper method of resection.

13. Describe the method of 'contouring' in the field.

14. What is a 'distribution map' ? Explain fully. Describe how it is made.

15. Plot the following data : Scale 1 inch to 100 feet : Close the traverse :—

| Station. A To | Distance in feet. | Angles in degrees |  |
|---|---|---|---|
| B | 169 | ABC | 41 |
| C | 122 | BCD | 277 |
| D | 76 | CDE | 108 |
| E | 221 | DEF | 61 |
| F | 175 | EFA | 126 |

16. Plot the following data on the scale of 1 inch to 200 feet. Close the traverse :—

| Station. | Angles in Deg. | Distance in Ft. |
|---|---|---|
| A | 58·5' | AB 845 |
| B | 95·3' | BC 626 |
| C | 80·3' | CD 653 |
| D | 102·4' | DE 210 |
| E | 203·1' | EA 434 |

17. Plot the following open traverse on the scale of 1 inch to 100 feet. It is known that the distance between A to L, as the crow flies, is 457 feet. Adjust the error of plotting, if any.

|      | Directions in Deg. | Lengths in feet |
|------|--------------------|-----------------|
| AB   | 180                | AB 100          |
| BC   | 275                | BC 174          |
| CD   | 215·4              | CD 95           |
| DE   | 282·4              | DE 143          |
| EF   | 255                | FF 245          |
| LF   | 133                | FL 205          |

18. In Fig. 15 on page 33 the length of the Base measures 500 yards. Give the distance between A and D ; and the bearing from B to E.

1

## MAP READING

Map reading is the art of making in the mind a rational picture of the ground represented by a map. Success in this art therefore requires a considerable practice. A map usually shows all sorts of details in a conventionalised manner. It is only the practised mind which can pick out quickly and correctly the required information from it.

The simplest form of map reading is *descriptive* which merely identifies and describes the various features depicted on a map. Descriptive map reading is all that is needed in military strategy or route marching. But for the geographer map reading should also be *analytic* and *deductive*. He should not only describe the facts shown on the map, but also analyse them and make deductions from them. This wider form of map reading demands not only the knowledge of conventional symbols, but also the understanding of Physical Geography.

The first step in map reading is to familiarise oneself with the symbols used in the map. These are usually given at the bottom of the map. The portion of the map which gives these symbols or signs is called *'the characteristic sheet.'* A fuller characteristic sheet giving all signs used by the map-makers in a particular country is, however, printed separately by the government of that country, In India, it is printed by the 'Survey of India' at Calcutta.

The number, size and character of the symbols used will depend and vary with the scale and the object of the map. If the scale is large and a great variety of details is to be shown, the corresponding symbols or signs will also be varied accordingly.

The other steps necessary in map reading are to note :—

  (i) the scale and grasp the actual length of the ground shown by it ;

  (ii) the shape and the V. I. of the contours ;

  (iii) the drainage system which helps in visualising the general nature of the ground ;

  (iv) prominent features which help in identifying other objects, and determining your position on the map.

In map reading it is necessary that one should think in terms of relief. It is thus that one gains the ability to visualise the actual country which is so essential for a successful map reading.

### MAP-SETTING

To read the map in the field is to identify the objects there with their representations in the map. This cannot be done successfully without 'Setting' or 'Orienting' the map. Setting or orienting the map means placing it in such a way that the object shown on the map will appear in the same *direction* as their actual counter-parts on the ground. In other words, the NORTH point of the map points to the north points of the field.

A map may be set by :—

  (i) Compass ; or

  (ii) Objects recognisable both on the map and in the field ; or

  (iii) the Sun.

#### (i) BY COMPASS

(*a*) Bringing the needle to coincide with the line of the magnetic north.

On most of the survey maps in use a line pointing to the magnetic pole of the earth is drawn in one corner. This line is often shown forming an angle with the line showing true north which points to the geographical North Pole. To set the map with the magnetic line, place

4

the compass on the map in such a way that its axis ($0°$—$180°$) lies exactly on this line. If necessary, produce the magnetic line. Then release the compass needle which will then move. Now, turn the map round slowly without disturbing the compass until the needle coincides with the line of the magnetic north. As soon as this happens the map is set.

The direction of the magnetic north changes frequently and it is not, therefore, certain that the line of the magnetic north shown on an old map will coincide with the magnetic needle. This variation in the direction of the magnetic north can be shown by quoting the example of Paris, where the longest records of magnetic observation exist. In 1580 the magnetic line formed with the true north-south line an angle of $9\frac{1}{2}°$ to the east of it. In 1810, however, this angle measured $22\frac{1}{2}$, to the west of the line. At London, this angle measured $12°$, $13.7'$ W. in 1931 and $11°$, $9.5$ in 1937. The magnetic variation for India is, however, negligible at present. For Allahabad it was $0°$, $10$ W. in 1931.

In cases of considerable magnetic variation, therefore, it becomes necessary to find out the actual variation for the year and on that basis make an angle with the north-south line on the map. The new line drawn to form this angle should now be used for setting the map.

(b) Taking the bearing of a distant object which can be recognised on the map.

Take by means of the compass the bearing of a prominent and distant object in the field. On the map now draw a line connecting your position with this object. Place the compass on this line so that its axis ($0°$—$180°$ line) coincides with it. Now, turn the map round until the degree of the bearing on the inner circle of the dial is opposite to the lubber mark inside the box. The lubber mark is a fixed mark on the compass in direct line with the sight-line. This method of map-setting eliminates the question of magnetic variation or compass error. It can be followed without the help of the north-south line.

(ii) BY RECOGNISABLE OBJECTS

(a) From known position (24 A, below.)
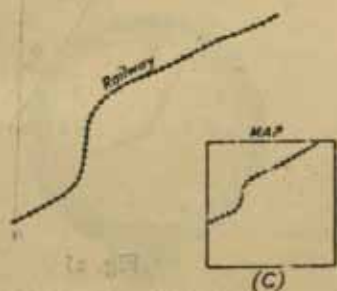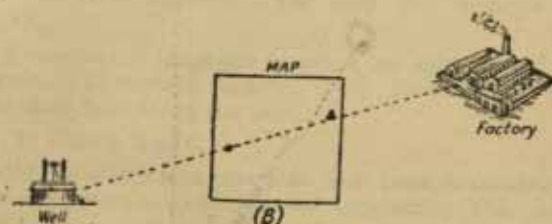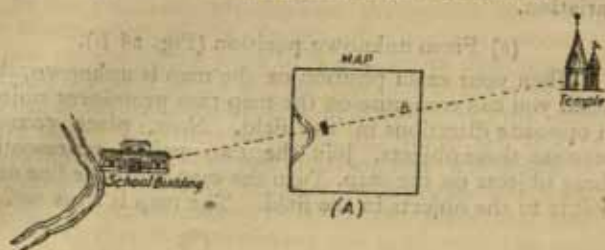


Fig. 24

When you can recognise on the map your own position and also that of some prominent object in the field, join the two points on the map by means of a pencil. Now rotate the map until this line actually points to the dis-

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tant object in the field. The map is now set. This is the easiest method and eliminates all questions of magnetic variation.

(b) From unknown position (Fig. 24 B).

When your exact position on the map is unknown, but when you can recognise on the map two prominent objects in opposite directions in the field. Now, place yourself between these objects. Join the two points representing these objects on the map. Turn the map until the line on it points to the objects in the field. The map is thus set.



Fig. 25

(c) From straight features on the map (Fig. 24 C).

When you can recognise on the map some road, canal or railway line, select, its straight stretch. Then hold the map in such a way that its representation on the map is parallel to the actual stretch in the field. This method is only approximate.

### (iii) BY THE SUN

(*d*) With a Protractor.

In the Northern Hemisphere the sun is due south, for places north of the Tropic of Cancer at noon. It travels 15° for every hour in a clockwise direction. By nothing the time of the day we can know the number of degrees it has travelled beyond, or is short of, the north-south line. Suppose it is 10 c.m, *i.e.*, there are still two hours before noon. In two hours the sun will travel 30°. We, therefore, make an angle of 30° with the north-south line of the map to the east of it. Now, place the map in such a way that the line making this angle with the north-south line faces the sun. The map will then be set. (Fig. 25).

Sometimes, a large pin is stuck at the end of this line which will throw a shadow. Now, turn the map until this shadow falls along the line.

(*b*) With a Watch.

Hold the watch face upwards and turn it so that the hour hand points towards the sun (neglecting the minute
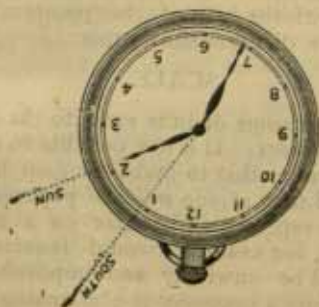


Fig. 26

hand). Now imagine a line dividing the angle formed by the hour hand and an imaginary line from the centre of the dial to the figure 12 on it. This bisecting line will

show the south in the northern hemisphere. Now, holding the watch steady turn the map slowly until the north-south line on the map coincides with the bisecting line. The map is set.

[NOTE—When summer time, which is one hour ahead, is used, the figure or 1 instead of 12 should be used.]



*Pole Star*

*Pointers*

Fig. 27

MAP READING

The north is also determined at night by the Pole Star (Polaris). To set the map its north point should be turned towards the Pole Star. The Pole Star can be easily found in the heavens with the help of the 'pointers' in the Great Bear. The above diagram shows this.

SCALE

Every map has some definite ratio to the earth, or part of it that it represents. It is not possible to make the map life-size. Remember that to make the map life-size of the equator it would take 25,000 miles of paper. Even ordinary things cannot be represented life-size on a map. Even a small class room, for example, would require a size of the paper that would be unwieldy and impossible to obtain. A scale is therefore a necessity in the making of a map.

The value of the map for the study of the earth is recognised. This value arises out of the fact that the map is a *reduced* representation of the earth or a part of it. What is the amount of reduction can only be known by the scale of the map. The scale is the expression of relationship

between two different quantities, ground distance and map distance.

The device of the scale is a great panacea, a medicine for all ills. You can map with its help any size of the area, large or small, on the paper you have got. The same area can be represented in different sizes according to the size of the paper. But to know the size of the area represented on the map it is necessary to know the scale of each map. As it is not possible to know it just by looking at the map, the scale must be written and indicated in some other way under the map. The need for this will be apparent from the following diagram:

A room 20 feet by 40 feet is mapped on three different scales. The three plans will appear as follows :—
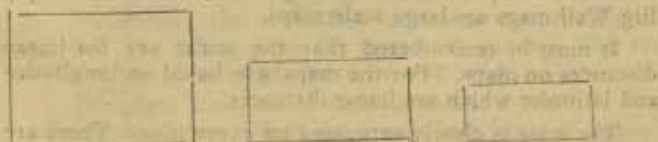


Fig. 28

It will be seen that all the three rectangles are alike, except for their size and therefore it is not possible to know the size of the room without knowing the scale, which must therefore be indicated underneath the plan.

Distances between objects on the ground can be measured from the map, because every map bears a fixed ratio to the ground it represents. This ratio is called the *scale* of the map. The scale is simply the relation of the size of the map to the size of what it shows. To find out distances from the map this *ratio between the map and the ground* must be known.

A scale is said to be *large* or *small* according to the *size* of the paper used to represent a certain area. Large and small are only comparative words. For example, in the map drawn on the scale of 1 : 2,000,000 one inch of paper is used for representing 2 million inches of ground.

In another map drawn on the scale of 1 : 1,000,000 one inch of paper is used for representing only 1 million. That is to say, in comparison to the former scale the size of paper used to represent the same area in the two scales will be larger in the second scale. The second scale is therefore the larger scale. A convenient method to compare two scales is to compare their denominators. *Longer the denominator smaller is the scale.* If the scale is given as statement, then the smaller the number of miles, the larger is the scale, smaller the paper, smaller the scale and vice verse. The scale of 1 mile to 1 inch and above (2 inches to a mile, etc.) are described as large scale maps. The scales below it (80 miles to 1 inch) are described as small scale maps. The atlas maps are small scale maps. Big Wall maps are large scale maps.

It must be remembered that the scales are for linear distances on maps. For the maps are based on longitudes and latitudes which are linear distances.

The scale is clearly expressed on every map. There are three ways of expressing it :—

   (i) By a simple statement; *e.g.*, Scale 1 inch to 4 miles. This means that four miles on the ground are represented by one inch on the map.

   (ii) By the ratio, known as the Representative Fraction (R F.) ; *e.g.*, 1 : 1,000,000 or 1/1,000,000. This means that one unit on the map represents 1,000,000 units on the ground. The advantage of expressing the scale by R. F. is that it can be converted into any unit of measurement. For this reason it is applicable to maps produced in any country irrespective of the unit of measurement used. For instance the above R. F. can mean '1 cm. on the map represents 1,000.000 cm. on the ground'; and also '1 inch on the map represents 1,000,000 inches on the ground'.

   (iii) By plane scale. This is graphical representation of the scale for quick reading. It has the advantage that the distances can be found out without

the need of any conversion or calculation. All that is necessary is to tick off the desired distance on the map on a paper and place it on the scale. The actual distance on the ground can now be read off the scale.

The plane scale is a straight line drawn on the map and subdivided on the same ratio as the map bears to the ground. The subdivisions are marked by the distances they will show on the ground. The major divisions to the right are called the 'primary' division; while the minor divisions to the left are called the 'secondary' divisions. The numbers, and the primary divisions are for whole, secondary divisions are for decimals.

Sometimes, the secondary divisions are divided in a special way which gives the DIAGONAL SCALE. This scale enables two decimal places to be read off it.

The plane scale can be adapted to show various types of measurements. Thus there may be a 'scale of paces,' a 'scale' of revolution,' or a 'time scale.' The object of these scales is to determine without actually measuring the ground, the distance that has been covered after a number of paces, revolutions, or time.

This is also called the Graphic or Graduated Scale.

## CONSTRUCTION OF THE PLANE SCALE

The first thing to be done in drawing a plane scale is to decide upon any particular distance that will be represented by a straight line to be drawn on the same scale as the map itself. It is this straight line that is the plane or the graphic scale. In the small scale maps the distances measured are generally long distances. They are generally in miles. In large scale maps, on the other hand, the distances measured are short distances generally, say in yards or feet. The plane scale for a small scale map therefore shows miles or sections of miles. The plane scale for a large scale map, on the other hand shows yards or feet.

When the distance to be represented has been selected, a straight line of the proper length to represent that distance on the scale of the map is drawn and divided into sections.

When the scale is given as a statement (that is to say, so many inches to one mile, or so many miles to one inch) there is no difficulty in finding the correct length of the straight line to represent the selected distance.

Thus in Fig. 31 the plane scale is drawn for a map whose scale is 1 inch to 1 mile. The distance selected for measurement on this scale is 5 miles. Obviously, on the scale of 1 inch to 1 mile this distance requires a line of 5 inches. The line is subdivided into five equal parts, one part for one mile. The first of these parts is set apart to be subdivided further into smaller sections to measure distances smaller than one mile. This part of the plane scale is called "the secondary." The other parts are meant to measure full miles, and are numbered from 0 to 4 towards the right. These parts are known as "the primaries." The idea of numbering the primaries from the 0 is that the secondary is not really a part of the main scale. It is only added on to the main scale. For its subdivision are not uniform with the divisions of the main scale or the primary. The numbering and the unit of measurement given in the scale in Fig. 31 should be carefully noted.

To divide a straight line accurately, draw another straight line of sufficient length making with it an angle of 20° to 30°. Divide this line into the number of sections required. Draw parallels from the points of division to the first line. The points where these parallels intersect the line are the required points of subdivision. Rub off the parallels and the second line. This process is shown in Fig. 30.

When the primary divisions have been made, the secondary divisions should be made, in this case, into quarter miles, as the scale shows miles. The scale will then appear as in Fig. 31.

If the scale of the map were 1° inches to a mile, a line of six inches divided into four parts of 1°'' each, would be drawn. The first part would be left for socondaries and the rest would give three primaries.

This is a simple case of plane scale construction where the unit of measurement of the scale is indicated.

Where the scale of the map is given as a fraction, that is R. F., the finding of the correct measurement of the line of the plane scale may appear to be somewhat difficult. It will be easier, however, if we adopt the unit of the measurement of the distance selected for representation on the plane scale to be the unit of measurement of the R. F. also. It has been pointed out before that in the English-speaking countries the numerator and the denominator of the R. F. are supposed to stand for inches. That is to say, 1 inch of the map represents so many inches of the ground. Now if we take them to be miles or yards or feet according to the distance that we want to show on the plane scale, the calculation of the length of the line to be drawn for the plane scale becomes very easy.

In Fig. 32, the scale of the map is 1/100,000. The distance selected to be represented on the plane scale is 5 miles. Now, to find the length of the straight line needed to draw the plane scale we assume the R. F. to be in miles. That is to say, 1 mile of the map represents 100,000 miles on the ground. To find the length required for 5 miles on this basis we proceed as follows :—

100,000 miles are represented by 1 mile or 63,360 inches

Therefore 1 mile is ,, $\dfrac{63,360}{100,000}$ ''

Therefore 5 miles are ,, $\dfrac{63,360 \times 5}{100,000}$ ''

Or 3·1 inches.

Now draw a straight line measuring 3·1 inches and divide it into primaries and secondaries as in Fig. 32 to get a plane scale for a map drawn on 1/100,000.
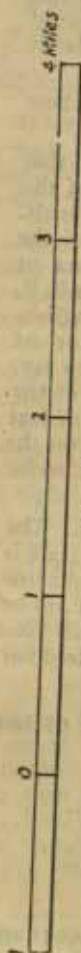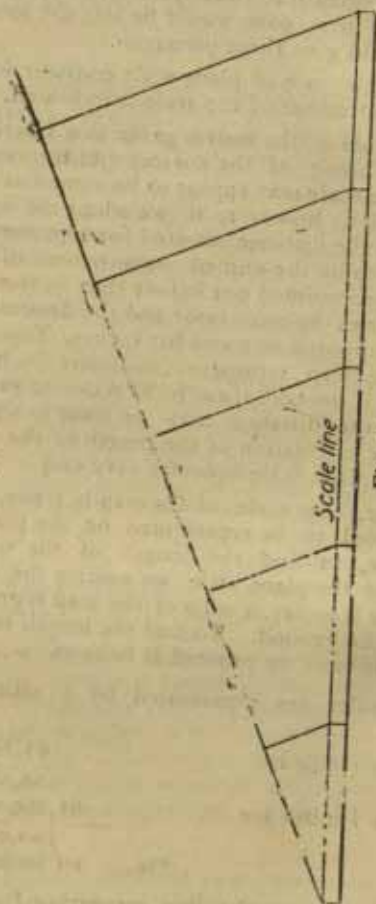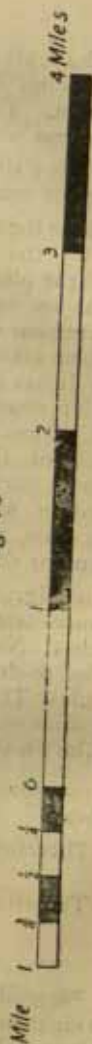
Fig. 29

Fig. 30

Scale line

Fig. 31

Mile

In large scale maps where one mile on the ground is represented by several inches on the map, the practice is to draw the plane scale showing yards, or feet.

To construct a plane scale for 1/25,000 showing yards, we shall take 3,000 yds. for representation. A simpler method for constructing yard scale from an R. F. is to suppose the unit (the numerator) to be a yard which is equal to 36 inches. In the above case, 25,000 yds. on ground are thus represented by 36 inches on the map. Therefore, 3,000 yds. will be represented by 4.3 inches. Now, draw a straight line of 4.3 inches and divide it into two primaries for 1000 yds. each, and one secondary subdivided into four sections for 250 yds. The scale will then appear as in Fig. 33.

A Scale of Paces is sometimes appended to the scale of yards to determine the distance covered by a certain number of paces. The standard military pace is 2 1/2 feet or 120 paces to 100 yards. Under the 100 yds. section of the scale therefore should be written '120 paces'.

A Time Scale is also added to maps used in marching. For this purpose, the speed of march per hour is given and the scale of the map is also known.

To construct a time scale for the speed of 2 1/2 miles per hour on a map drawn on the scale of 4 miles to one inch, select a suitable number of hours. Find out the distance that will be covered within this time. Then draw a straight line to represent this distance on the scale of the map. Divide this line into the number of *hours* and mark the usual primaries and secondaries. Suppose the number of hours selected is 6. Then distance covered at 2 1/2 miles per hour will be 15 miles. At 4 miles to an inch this distance will be represented by 3 3/4 inches. Now, draw a straight line of this length and divide it into six equal parts representing hours. The secondary may be subdivided into quarter hours. The scale will appear as in Fig. 34.

We have so far explained the method how the plane scales are constructed. In practice however, it is seldom

In large scale maps where one mile on the ground is represented by an inch or inches on the map, the practice is to make the plain scale a fixed number of feet, or . . .

To construct a plane scale for 1/4" . . . . . . . . . . A simpler . . . . . . . . . . . . . . . . . . . from an R.F. is to . . . . . . . . . . . . . . . . . . . . . . . a yard which is . . . . . . . . . . . . . In the . . . . . . . . . . . . . . on . . . . . . . . . . . . . . . . . . inches on the map . . . . . . . . . . . . . . represented by 63 inches . . . . . . . . . . . . that . . . . . . . and divide it into . . . . . . . . . . . . . some . . . . . . . . . . . . . . . . . . . . secondary . . . . . . . . . . . . . . to . . . . . . . . . . . . . . scale will . . . . . . . . . . . .

. . . of the . . . . . . . . . . . . . . . . . . . . . . scale . . . . . . . . . . . . . . . . . . . . . covered by a certain . . . . . . of . . . . . . . The . . . . . . . . . . . . . . . . a . . . . . . . . . . . . . gradually take the . . . direction . . . . . . . . . . . . . . . . . . The . . . . . . . . . . . . . . . . . . . . . . . . more . . . . diminishing. . . . . . . . . . . . . . . . . . . . . . . . . . is given . . . . . . . . . . . . . . . . . . .

. . . . . . . . . . . . . . . . . . . . . . . . . . . of 1/4 mile . . . . . . . . . . . . . . . . . . . . . . 4 miles to one . . . . . . . . . . . . . with . . . . . . . . . . . . . . . . . . Fishing-line . . . . . . . . . . covered . . . . . . . . . . . . . . . . . Then draw . . . . . . . . . . . . . . . . . . . . . . on the . . . . . . of the . . . . . . . . . . . . . . . . miles or . . . . and . . . . . . . . . . . . . . . . . . . . . . Suppose the . . . . . . . . . . . . . . . . . . . . . . Then . . . . . . . . . . . . . . . . . . . . . . . . . . 1/4 mile to an . . . . . . . . . . . . . . . . represented by 1.4 miles. . . . . . . . . . . . . . . . . . . . . . . . . off.000 is into six . . . . . . . . . . . . . . . . . The regular map, or . . . . . . . . . . . . . . . . . . The plan will appear as . . . . .

We have . . . . . . . described how the plane scales are constructed. In practice, however, it is often . . .



Fig 32

Fig 33

Fig. 34

Scale labels (Fig 32): Mile   1/4   0   1   2   3   4 Miles ;   5   4   3   2   1   0   Hours

Scale labels (Fig 33): 1000   750   500   250   0   1000   2000 Yards

Scale labels (Fig 34): 1   3/4   1/2   1/4   0   1   2   3   4   5 Hours

necessary to construct the plane scales in map reading. The necessary scales are given on a protractor, and they can be copied on the map, if desired.

A DIAGONAL SCALE is a device for dividing the secondary of a plane scale very accurately. Usually, however, the method is used for providing a decimal scale. To construct a diagonal scale for reading decimals, draw ten equidistant parallel lines above the scale line. Divide the top and the bottom lines of the secondary portion only into ten equal parts. Number these parts from o to 9 to the left. Now, join the o on the top to the o at the bottom, and the tenth part on the top to the tenth part at the bottom. This gives us a rectangle over the secondary. Then, join 1 on the top to the o at the bottom, 2 on the top to 1 at the bottom, 3 at the top to 2 at the bottom, and so on until all the points of division are joined This completes the diagonal scale. On this scale, the sections on the original scale line at the bottom show distances to one decimal place, while those on the successive parallels show distances to two decimal places. To read ·57 on this scale, reach the point marked 5 on the scale line at the bottom and from there follow the diagonal line upward until you reach the parallel line marked 7. The intersection of the diagonal line (marked 5 here) and the parallel line (marked 7 here) gives the required distance. The following shows the construction of the diagonal scale :—
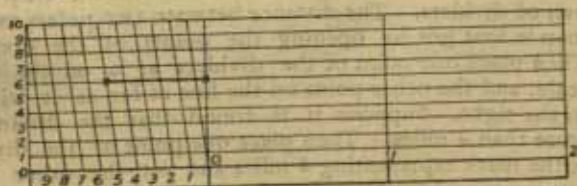


Fig. 35

Comparative scale. Recently the word comparative scale has been used for a graphic scale showing two different units of measurement, say cm. and inches, on the same line.

### CONVERSION OF THE SCALE INTO R. F.

Sometimes, it becomes necessary to express the scale, shown by a simple statement or graphically, by R. F. In such cases the simple rules are :—

1. When the scale is given in miles to an inch ; *i.e.,* in small scale maps, *multiply 63,360 by the miles given. This gives the denominator of the* R F.

2. When the scale is given in inches to a mile ; *i.e.,* in large scale maps, *divide 63,360 by the inches given. This gives the denominator of the* R. F.

For example, if the scale is 5 miles = 1 inch, the R. F. will be

$$63,360 \times 4 = 53,440$$
$$= 1/253,440,$$

### Or

If the scale is 6 inches = 1 mile,

the R. F. will be

$$63,360 \div 6 = 10,560$$
$$= 1/10,560.$$

### MEASURING DISTANCES FROM THE PLANE SCALE

The meaurement is generally done with the help of a pair of dividers. The distance between two points on the map is first got by opening the points of the dividers. Then place one point of the dividers at o on the plane scale, and the other point on the line as far as it will go to the right. Suppose it is found that the distance is more than 4 miles. Then place one point of the dividers at the mark representing 4 miles and let the other point touch the secondary division. Note where the point touches the secondary, add it to the 4 miles read on the primary division. Suppose here it touches the section marked 1/2. Then the distance required is 4 + 1/2 = 4 1/2 miles.

If a map has no scale given, its scale can be ascertained by the fact that 1 degree of latitude is roughly equal to 69 miles. For accuracy measurement should be taken in the centre of the map. Suppose we find the measurement of 1 degree on the map to be 2 inches. The scale will be :—

34·5 miles to 1 inch

Or

1/2,185,920

#### SCALE OF SLOPES

A scale of slopes is sometimes constructed to measure from contours the slope of the ground between any two points. It furnishes a very rapid and convenient method of getting the slope. The scale is made by marking of along a straight line the lengths of the H. E. for every degree of slope. The lengths of the H. E. are drawn on the scale of the map. The divisions of the line representing the degrees bear a simple relationship among themselves. For example, the length representing 1° of slope is twice that representing 2° and three times that representing 3°, and so on. Therefore, all that is necessary to do is to find the H. E. of 1° and the rest can be easily computed by dividing this length by the degrees.

The formula for getting the length of the H. I. of 1° for any map is as follows :—

H. E. $= 57·3 \times$ V. L. (in feet) $\times$ 12 (inches) $\times$ R. F.

Thus the H. E. for 1° on a map on the scale of 1/63,360 with the V. L. of 50 feet will be :—

$$\frac{57·3 \times 50 \times 12 \times 1}{63,360} = \frac{34,380}{63,360}$$

$$= ·54 \text{ inch.}$$

The scale will now appear as under :—



Fig. 36

The first division will be ·54 of inch, the second, of half of ·54" ; the third, of one-third of ·54" ; and so on.

A scale of slopes can serve only for the map and the V. I. for which it has been constructed.

For measuring the slope, take the distance between two consecutive contours on the map on a pair of dividers. Place this distance along the various divisions. Whatever division it fits or is near about, that gives the slope between those contour lines only.
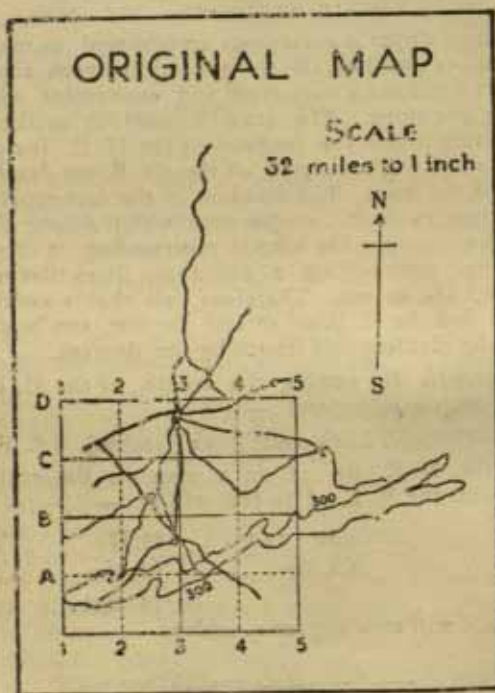


# ORIGINAL MAP

### Scale
32 miles to 1 inch

Fig. 37

## CHANGING THE SCALE

Sometimes it is necessary to change the scale of the map by enlarging or reducing it. This map is done either, by a mechanical device known as the pantograph, or by the method of squares.
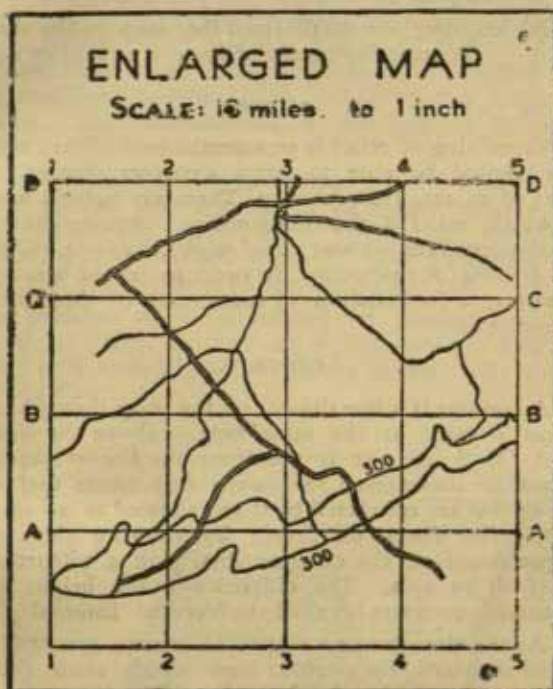


Fig. 38. Here a portion has been enlarged by the method of squares.

The method of squares consists in

(i) drawing squares to represent one mile *on the map* on the old scale ;

    (ii) drawing squares to represent one mile on the
         sheet of paper on the new scale ;

    (iii) subdividing the squares both on the map and
         on the paper into a fixed number of subdivi-
         sions, say five subdivisions for every mile
         square ;

    (iv) copying the detail from the map to the sheet of
         the paper by means of the eye, square by square.

### RELIEF

Visualising of relief is an essential part of map reading.
One should be able to form a correct picture of the
relief of an area from its map  There are various methods
by which relief is shown on a map.  Among these maps
be mentioned the *contours, spot heights, hachures, hill shading*
and *layering* (or colouring). In order to get the best results,
however, a combination of some or all of these methods
is employed.

### CONTOURS

A contour is a line drawn on the map through all the
places situated at the same height above the mean sea
level (M. S L.). It is therefore the *line of equal height.*
A contour line marked 3oo on the map means that all the
pla es that are connected by it are situated at an elevation
of 3oo feet above sea level. By showing elevations or
slopes therefore the contour lines give a picture of the
relief of an area. The difference in the height of two
successive contours is called the Vertical Interval (V. I.).

As the elevations or slopes in nature are not distri-
buted regularly, the contour lines which show them on
the map must also be irregular. They appear on the
map therefore as curving lines ; in some places close
together and in others far apart. Sometimes, they form
on the map closed Figures of irregular shape ; while in
other cases their ends pass to the edges of the map.  In
theory, however, the ends of the contour lines must
close, for the shape of the earth is round. The round

shape of the earth, thus leads us to the principle of the contour lines. We know that the earth is surrounded by water which has filled the depressions, leaving the elevated portions high and dry. If the water surrounding the earth were to rise, say 10 feet, above the existing level, it will drown all places situated at an elevation of 10 feet above its old level. If this water again subsides to the old level, it will leave a line mark indicating all the places that were drowned formerly. This line will be an irregular but closed line owing to the shape of the earth. The representation of this line on the map will be called the contour line.

Next time, when the water rose, say 20 feet, it will form a second line which will be higher than the first line. This rise and fall of water around the earth can be imagined to give to the map the lines indicating the elevation of various parts of the earth's surface.

The principle can be illustrated by placing a model of irregular shape in a tub and adding water to cover it. Suppose such a model to be placed in the tub in the following diagram :—
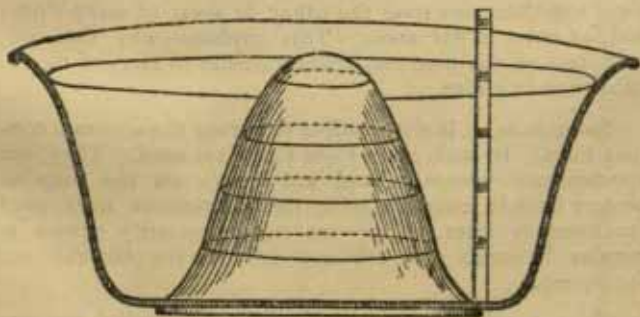


Fig. 39

The bottom of the tub represents the shore line. When water is added to the tub it touches the first line.

Successive supplies of water touch the higher lines. These lines will appear on the map as closed circles shown in Fig. 4o.
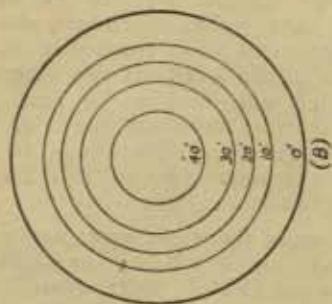


Fig. 4o

It will be remembered that when water rises it covers a large surface where the land is flattish; that is to say, where the slope is gentle. But where the slope is steep the water is heaped up without covering large area. The result is that the lines marking the rise of the water are close together, one over the other, in areas of steep slope, and far apart in flat areas. This explains why the contour lines on the map are closer together in areas of mountains than in plains.

Sometimes, it is not possible to survey the accurate contour lines. In such cases *Form Lines* are used. They are approximate contours and are shown on the map as broken lines in contrast with the continuous lines used for contour lines. They are not necessarily drawn at regular intervals and are not reliable for accurate information.

Contour lines are used for showing relief features only on large scale maps. The reason is that the intervals between contours are so small that they cannot appear on small scale maps. Contours are common features of survey maps only.
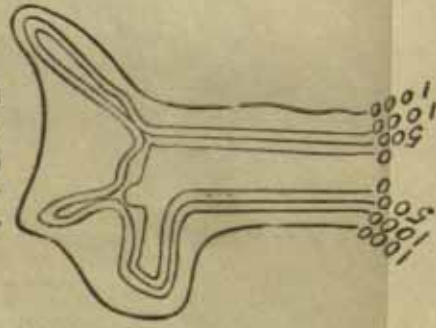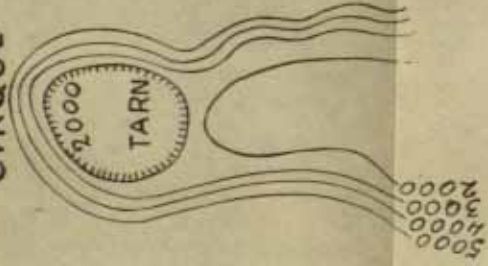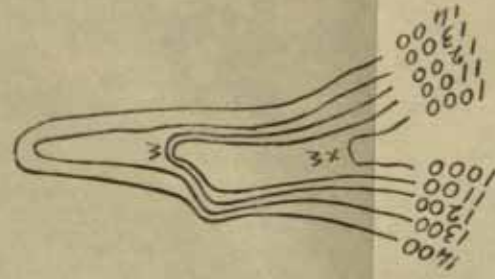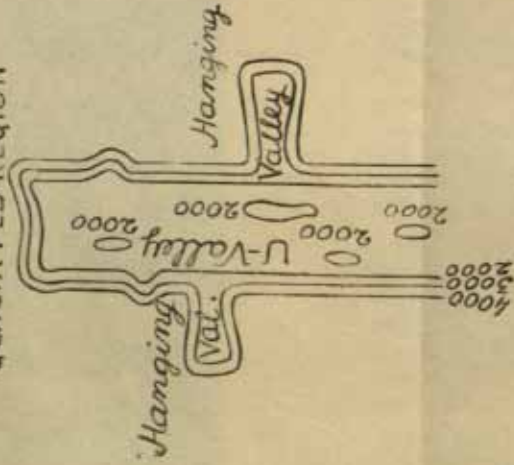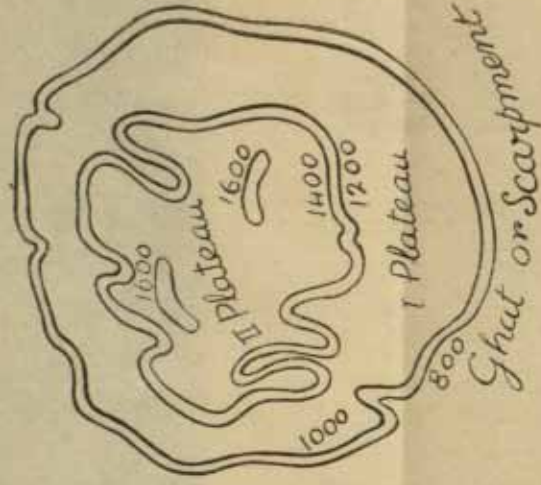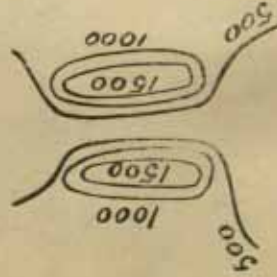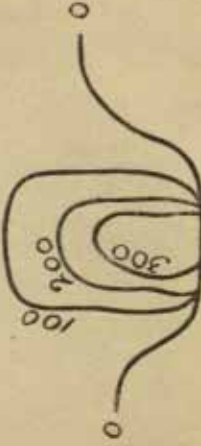
Fig. 41

For high relief, *i. e.*, mountainous religions, the contour interval is high, say 1000 ft. or 5000 ft. or even more. For plateaus and hilly areas the interval varies from about 100 ft. to 500 ft. On plains the contour interval varies from about 20 ft. to about 50 ft.

In a mountainous and plateau regions there are many contour lines ; some of them closed, others open at both ends. But in plain regions the contour lines are few and far apart. There are generally no closed contour lines in the plains. Wherever such closed contours occur in the plains, there is only one enclosed line. No second contour line follows it. Depression contours are marked by a small tick towards the side in which the depression starts. Lakes are marked by such a contour.

In the plateau two things are outstanding : two or three contour lines very close to each other bounding the whole plateau towards the plain. These contours mark the steep slope (scarpment) of the plateau. In the interior of the plateau, a large space is enclosed within single contour lines of high value. There are several closed contours to mark the hillocks and ridges.

The contour representations of the common relief features are given in the attached sheet (Fig. 41).

In Fig. 42 is shown how certain forms of relief appear on the contour map.

In the diagram, four characteristic shapes of contour lines will be noticed :—

> (1) Closed contours, showing hills ;
>
> (2) Contours bending away from the hills showing spurs and salients ;
>
> (3) Contours bending towards the hills, showing valleys or re-entrants ;
>
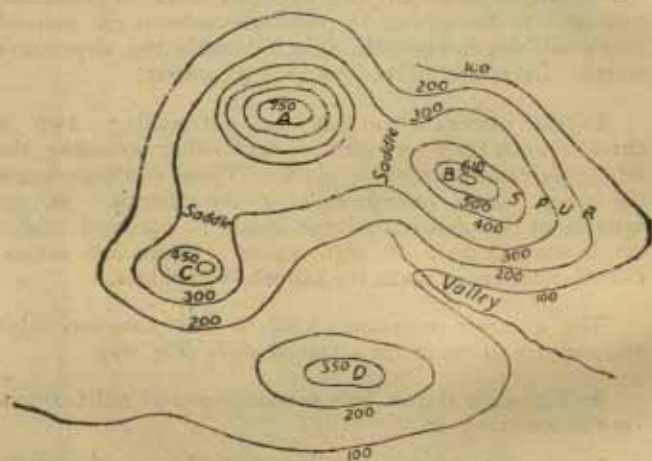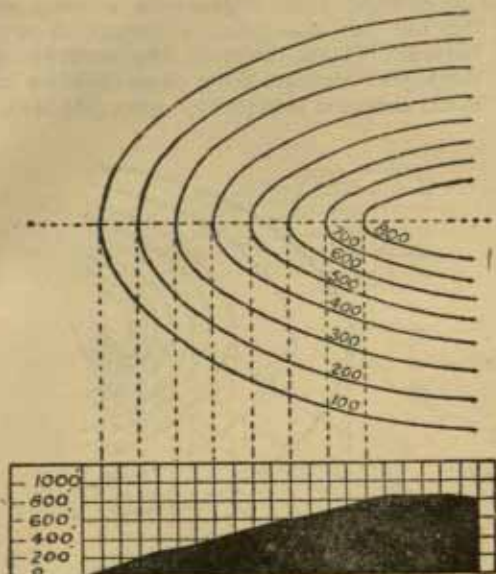> (4) Contours joining hills, showing saddles.

Fig. 42

By a little pract'ce these characteristic shapes will help us to form a mental picture of the various relief features they represent.

Contour lines give us an idea of the slope of the ground also. Where they are drawn close together the distance to be travelled forward is small in comparison

*UNIFORM*

Fig. 43

with the height that had to be claimed. This indicates a steep slope of the ground. Where, on the other hand, the contour lines are drawn far apart, the distance to be travelled forward to the next contour line is long compared with the height to be climbed. This indicates a gentle slope.

A survey of the land surface reveals that the slope of the ground is of three classes :—

1. *Uniform slope*, where the ground has the same type of slope throughout. This type of slope is represented on the map by the contour lines being equidistant (Fig. 43)

2. *Concave slope*, which begins with a steep slope at the top but ends with a gentler slope at the bottom. This is shown on the contour map by the higher contours being close together and the lower contours being wider apart (Fig. 44).
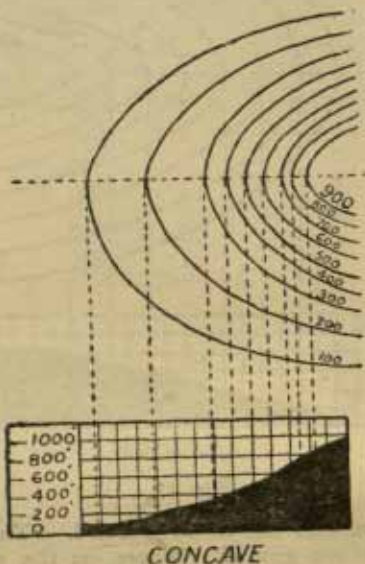


CONCAVE

Fig. 44

3. *Convex slope*, which begins at the top with a gentle slope, but ends at the bottom with a steeper slope. It is shown on the map by the higher contours being wide apart and the lower contours closer together (Fig. 45).

Generally, the contours representing a *valley* are further apart at the bottom than at the top and therefore its

sides are *concave*. The contours representing a *spur*, on she other hand, are closer together at the bottom than at the top and therefore its sides are *convex*. The figures thowing the height of the contours are always placed on the side of the line on which the ground rises. The
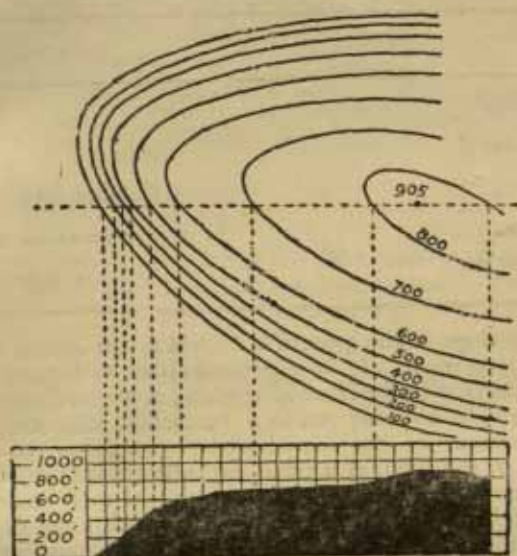


CONVEX

Fig. 45

pirection of the slope can therefore be known even by looking at the placing of the contour figures. Similarly, the top of a hill or the bottom of a valley may be recognised on the map by the presence of two adjacent contours marked with the same height.

In map reading, it becomes necessary sometimes to measure from the map the slope of the ground. The

utility of this measurement is for the builders of roads and railways and the users of roads. For the slopes beyond a certain limit cannot be used for certain kinds of traffic. The following table gives an idea of this limit :—

### Maximum Practical Slopes for Certain Purposes*

| Slope | | Purpose |
|-------|--------|---------|
| Degrees | or Gradient | |
| 1° | 1/60 | Railways. |
| 3° | 1/20 | First class roads. |
| 26° 45° | 1/2 | Individuals can negotiate with great difficulty. |

The slope of the ground is defined as the incline to the horizontal plane. It is expressed either as degrees of an angle made with the horizontal plane, or as gradient which is the rise of so many feet in a horizontal distance. The measurement of the slope is done by means of the cl nomoter or the level, as pointed out elsewhere in this book. The gradient is computed by dividing the total rise of the ground between two points by the horizontal distance separating them. The total rise is found out from the vertical interval of the contours and the horizontal distance from the scale of the map. The horizontal distance between two points whose gradient is to be calculated is called the 'Horizontal. Equivalent.' Thus, the formula for getting the gradient is $\dfrac{\text{V. I.}}{\text{H. E. (in feet)}} = \text{gradient}$.

---

*Quoted from U.S. Military Services Regulations, Appendix 7.

For example, if two points A and B are separated on a map by four contour lines drawn at the V. I. of 250 feet, then one point is 1,000 feet (250' × 4 contours lines) higher than the other. If these points are 1·14 inches apart on a map drawn on the scale of 1 inch to 1 mile, their horizontal distance on the ground must be 1000 yards or 6000 feet. The gradient between them must

therefore be $\frac{1000}{6000} = \frac{1}{6}$. The gradient is 1 in 6. It

must be remembered that the gradient is always expressed with 1 as the numerator. The denominator may thus be with decimals if necessary. For example, a gradient of

6/15 will be expressed as $\frac{1}{2 \cdot 5}$.

If necessary, gradients can be converted into degrees of the slope angle by multiplying them by 60.* Thus, a gradient $\frac{1}{6}$ will be expressed in degrees as a slope of 10°; ($\frac{1}{6} \times 60 = 10°$).

Similarly, the degrees of slope can be converted into gradients by dividing them by 60. Thus a slope of 5° has a gradient of ($5° \div 60 = \frac{1}{12}$) $\frac{1}{12}$.

### INTER-VISIBILITY

Mutual visibility between two points or the extent of visible area from a particular observation point can also be determined from the contour map. Visibility between points depends, apart from any intervening features like trees or buildings, upon the slope of the ground separating them. It can therefore be found out from the map whether any two points are intervisible or not by the following methods :—

---

*The gradient is the tangent of the angle of slope (V.I./H.E.). The tangent of 1° is 1/57·3 or approximately 1/60. Hence, the multiplication by 60. For greater accuracy the multiplication should be done by 57·3.

1.  by the examination of the slopes as deduced from the contours on the map ;

2.  by the comparison of gradients ; or

3.  by drawing sections of the contours.

(1) It is to be noticed that concave slopes favour inter-visibility of points, while convex slopes do not. The points on the valley slopes, which are *concave*, are therefore *visible* from each other. But the points on the slopes of spurs, which are *convex*, are *not visible* from each other. Uniform slopes also favour visibility.

(2) Another method is to compare the gradients of the two slopes formed from any intervening feature to the two points. If the gradient between the higher point and the intervening feature is steeper than the gradient between the lower point and the intervening feature or it is the same, the points are intervisible. If, on the other hand, it is gentler than the other gradient, the points are not intervisible.

The following diagrams will help to remember this :—
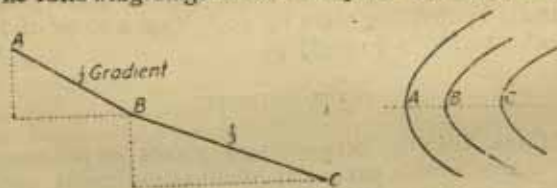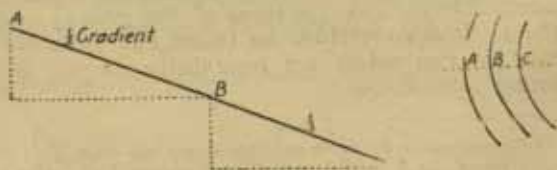


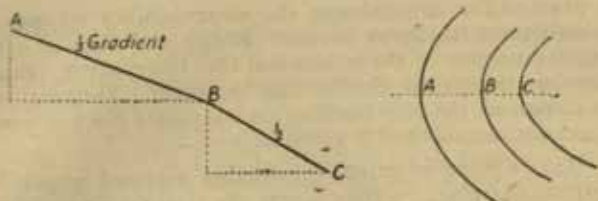Fig. 46.   Visible



Fig. 47.   Visible

Fig. 48. Not Visible

A simple arithmetical method of comparing the two gradients between the higher point and the intervening feature and between this latter and the lower point is as follows :—

Distance between the intervening point

| | |
|---|---|
| B and the lower point C is | 200 ft. |
| Distance between A and C is | 600 ft. |
| Difference in height of B and C is | 100 ft. |
| Difference in height of A and C is | 200 ft. |

Now, in 600 feet the line of sight between C and A rises 200 feet above C. In 200 feet from C and B therefore it should rise $\frac{(200 \times 200)}{600} = 6\frac{2}{3}0$ feet.

The line of sight will therefore be obstructed, as the intervening feature B rises 100 feet above C. The points A and C are therefore not intervisible. These points can be intervisible only when B, the intervening feature, rises above C 66 feet or less.

(3) A section is the outline of the intersection of the ground by a vertical plane. Sections are easily constructed from contour maps to present certain information from them in a more convenient form. They give an excellent idea of the comparative slopes, and also show the extent of the ground that can, or cannot, be seen from a given point. The 'dead ground' is that which cannot be seen from that point. A section is, however, seldom necessary

in practice for determining the intervisibility of points. Sometimes, a 'skeleton section' giving the line of sight and the heights of the points and the intervening feature may be enough to decide this problem. Sections may be drawn on the map itself or on a separate piece of paper. A convenient method is given below :—

Take a piece of paper, preferably squared paper for graphs, and place its edge along the straight line joining the two points on the map for which the section is to be drawn. Mark on the edge of the paper the points where it touches the various contour lines. Then draw, in the middle of the paper, at equal distances straight lines
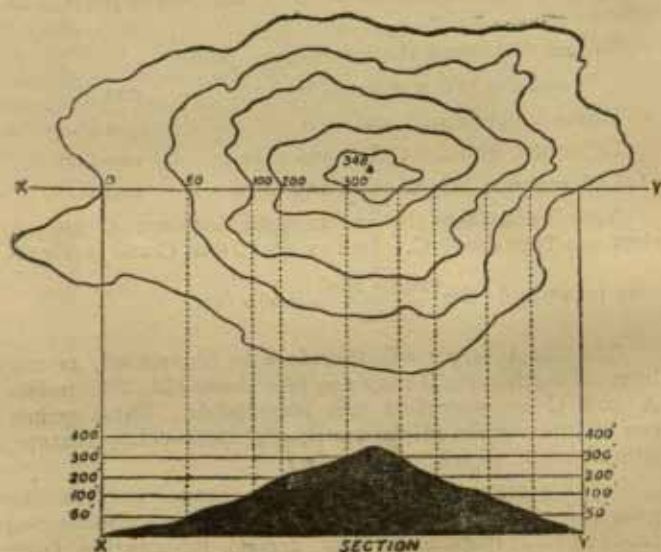


Fig. 49

parallel to the edge of the paper. The lowermost of these parallel lines should be the datum line and be marked o. The lines above it should be marked by the heights of the

contours touched by the edge of the paper; starting from the lower heights to higher ones. Now, drop perpendiculars from the points at the edge of the paper where the contour lines meet it. The perpendiculars should be to the corresponding parallel lines representing the various contours. Join the points of intersection between the parallels and these perpendiculars. This gives the required section or profile.

In Fig. 49 a section has been drawn in this way.

Care should be taken in using sections drawn from contour maps. It will be remembered that a number of the intermediate contours are only *interpolated* and not fixed by survey on the ground. Deductions based upon such contours are not therefore trustworthy.

For some other methods to determine intervisibility between points, the student is referred to 'Exercises in Cartography' by Prof. Debenham.

The prominence or the insignificance of the sections drawn from contours depends entirely upon the distance at which the parallel lines standing for the contours are drawn in the section. If this distance is large, the sections would stand out very high. If, on the other hand, this distance is small, the sections would appear low enough. It is, for this reason, that in drawing sections the exaggeration of this vertical scale is generally mentioned. It is often said that the vertical scale is ten times or twelve times exaggerated from the actual scale of the map. Now, it must be remembered that the distance by which the parallel lines for the contours in the sections are separated is much more than the actual distance by which the vertical interval (V. I.) of a contour would be represented according to the scale of the map.

Sometimes the data for section drawing are transferred from the map to a separate paper very elaborately. This is usually done in the case of winding roads where the

6

simpler method followed in Fig. 49 is not possible. In
the diagram (in B) on page 83 the section of a road has
been drawn. The road appears to be straight in the
section, but actually it is winding, as shown in the map
from which the section is drawn. (The map appears in
Fig. 50 below).
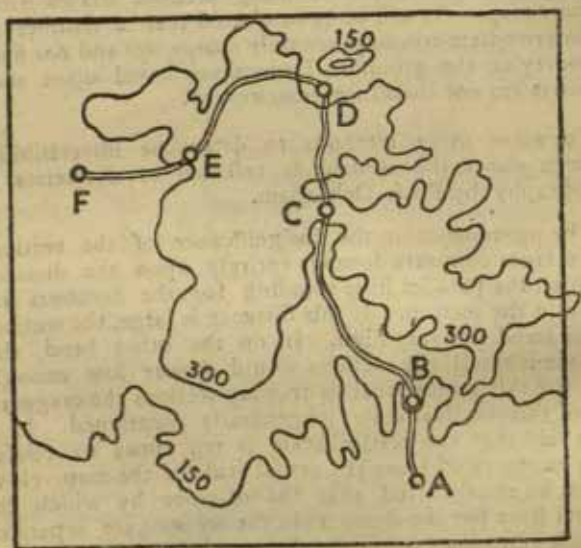


## SCALE: 1 inch = 1 mile

Fig. 50

Fig. 51
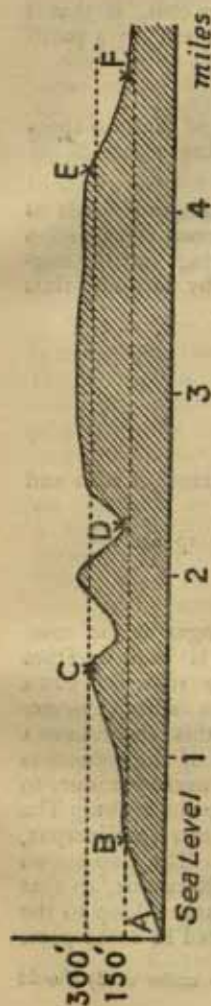
[VERTICAL SCALE EXAGGERATED 7 TIMES]

## HACHURES

Hachures are lines drawn in the direction in which water would flow down the hill. The slope of the hill is shown by the thickness and spacing of the individual lines. A steep slope is shown by heavy and closely drawn lines. But for gentle slopes they are fine and far apart. Darkly shaded areas therefore mark steep slopes and lightly shaded portions gentle slopes. Hachures do not give an accurate idea of the slope, though they give a good general idea of the shape of the ground. They are also a costly method. They also cover up the map and obscure other details in a hilly country. They are therefore seldom used in modern maps.

## LAYERING

In modern maps on small scale the area between contours is sometimes coloured by different tints. The lower levels appear with a light tint which deepens with each succeeding level. The chief advantage of layering is that it enables a quick comparison of the relative heights of widely separated areas on a map.

But its chief disadvantage, apart from its cost, is that it may give the impression that the area covered by a particular tint is all level.

## SPOT HEIGHTS

Spot heights show the exact heights of certain spots and are used in combination with all the methods of showing relief.

A comparative study of the above methods leads us to the conclusion that contour lines give exact information about slope and elevation; hachures bring out the ruggedness of the country; and layering by latitude tints emphasises the elevation above sea level.

## EXAMPLE IN READING*

Sheet No. 63 K/12 (Mirzapur Sheet)

Scale 1 inch to a mile

or 1/63,360

(including parts of Mirzapur and Banaras Districts and former Banaras State.)

The two outstanding features of this map are : —

(i) the Ganges, and
(ii) the Vindhyas.

From many points of view the Ganges is the more important feature, as most of the area is built up from the alluvium brought down by it. The river flows in a meandering course; in fact, due to the alluvial nature of the plain, all the rivers present in this sheet have a meandering course. There are two loops of the meanders of the Ganges in this sheet, one, the narrower one, to the left and the other, the wider one, to the right. The narrower loop is important because it centres on Mirzapur, which is the largest town on this map. The map shows that the current of water is always near Mirzapur, so that this part of the bed is never dry. The larger loop to the right is characterised by a very wide bed in some parts

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*The student is advised that the Survey map under study should be obtained from 13, Wood Street, Calcutta.

about two miles wide. A large part of this bed consists of dry sand.

Owing to the meandering nature of the river, the banks are shelving in some parts and steep in others. Where the banks are shelving the flood water of the river spreads over large areas in the neighbourhood. But where they are steep the flood waters are contained within them without invading the neighbouring area.

This is shown by the fact that on the side of the shelving banks, to avoid floods, the villages are situated far away from the river. On the side of the steep bank, on the other hand, they are situated close to the bank.

The Ganges is not bridged at any place in this map. It is a wide river which is very costly to bridge. It has therefore been bridged only where traffic justifies it. In this map we notice that there are no large concentrations of population on the other side of the river from which large traffic could come. Mirzapur and Bindhachal are the only towns with large population, but they are both on the same side of the river. So there is no need for a bridge in this area. From November to June the Ganges is crossed by a Pontoon bridge at Mirzapur. There are eight places on the Ganges in this map where there are permanent boat ferries. Three of these places are near Mirzapur, which is natural, considering that Mirzapur is the district and the largest town on this map and is therefore the focus of the area around it. Considering the number of boats at each ferry place, the most important ferries, outside Mirzapur are those at Bindhachal (connecting it with Harsinghpur) and Bhatauli Ghat (connecting it with Baraini and thence Kachhwa, the largest town on the north side of the river.)

All the tributaries of the Ganges on this map come from the South, from the Vindhyas. Among these tributaries, the most important ones are the following :—

    (i) Chatar Nadi,

    (ii) Kuardari, known in the middle course as Madho Nadi and in the lower course as Khajuri Nadi,

(iii) Harrai Nadi. (The famous Tanda Falls are situated on this river in its upper course).

(iv) Ojhala Nadi, joining the Harrai near Mirzapur.

Some of these tributaries are dry, except in the rainy season. This is specially true of the Khajuri Nadi. Besides these tributaries there are a number of Nalas which carry the surface drainage when it rains.

Some parts along the tributary rivers are marked by the badly cut up ravine lands. The most extensive area of ravines is found along the Chatar Nadi and the Harrai Nadi. The Ganges itself is characteristically free from ravines.

There are also a large number of tanks on this map. All, except two, are, however, small tanks. Some of the tanks are generally dry, except during the rains. There are two tanks, Tandadari Tal and Chandewa Tal, which are very big and have water throughout the year. The significance of the Tandadari Tal is that it supplies water to Mirzapur situated about nine miles to the north. The water is taken through a pipe line.

The Vindhyas and their foothills occupy about a third of the map in the south. They are a highly dissected plateau, with its steep escarpment facing the south or the east. The plateau is generally about 500 feet in elevation. It descends towards the north in two steps; the first step is about 550 feet above sea level and the second about 350 feet. The descent is very steep, making in some places a slope of about 7°. The Mirzapur-Robertsganj Road, for example, has a slope of about 5° which is considered to be a very steep slope for a road; the best roads have the *maximum* slope of 3°.

There are a number of flat rounded top hills both on the top of the plateau as well as at its foot. The highest hills are naturally those further south. Thus the Deophulwa to the east of the Robertsganj Road (683 feet) is the highest hill. This hill is a conical hill rising steeply on the top of the plateau. Other hills on the plateau are the Murli (648 feet), the Rajghat (571 feet) and the Bamhan-

dewa (5:5 feet). The Bamhandewa is characterised by a very extensive and flat top.

Among the foothills the most numerous are those situated in the south-eastern part of the map. The most conspicuous foothills are the Shanker Pawa (549 feet); the Tharpahra (500 feet), being joined by a saddle to another hill 490 feet high; the Kugahi (523 feet). Besides these, there are several low hills further north, the two important examples being the hills near Pahara Railway Station on the main line of the E. I. R, and the hills near the Rifle Range to the south of Mirzapur. These latter are only about 300 feet high.

The significance of the foothills lies in their giving rise to stone-quarrying.

The river valleys on the plateau are broad with steep walls. Note for example, the Valleys of the Jamthua and its tributary, the Dhaunia. Similary, the Valleys of the Kuardari and the Harrai in their upper courses on the plateau are broad ones.

But as these rivers cross the plateau to reach the Ganges to the north, they have to pass through narrow gorges with steep walls. This is true of almost every river coming from the south across the plateau. The most significant example is that of the Kuardari which passes through the longest gorge on this map.

Most of the area on this map is shown to be cultivated. The only areas which are not cultivated are on the plateau or in the ravines where the soil is unfit for cultivation. The plateau region and the hills are generally covered by mixed forests. These forests are most extensive in the area to the east of the Mirzapur-Robertsganj Road, and near the Tandadari Tal. The areas that are not covered by forests are covered by grass or scrub. The most extensive areas of this latter type are to the west of the Robertsganj Road and in the ravines of the Chatar Nadi.

The area shown on this map is predominantly an agricultural country. It is not an industrial region. The distribution of the population is therefore essentially

rural; i. e., it is found (i) scattered in small villages and (ii) is concentrated to some extent only in the market towns which very often happen to be also the administrative towns for the surrounding area Villages are more numerous in those parts where the soil is fertile than where it is indifferent. Generally, the soil near the plateau is less fertile than near the Ganges, specially to its north. Much larger villages are therefore found north of the Ganges than near the plateau. The region near the plateau is marked by small villages.

Mirzapur, being the district town and a great market for the produce of the area around, is naturally the largest town on this map. It is situated on the right bank of the Ganges where the steep banks of the river prevent the flood water from spreading to Mirzapur side. The river is also the narrowest in this part, so that it can be easily crossed.

Bindhachal, Khamaria and Kachhwa are the other towns of note. They are all administrative towns, while Khamaria has the distinction of having a carpet factory.

The plateau region is almost without any settled population. The most populated parts in the south are to be found in the wide valleys of the river where agriculture can be carried on. Of these valleys, the Valleys of the Chatar Nadi and its tributary the Simaria, are the most important in this respect.

Apart from the hills, there are four areas which are particularly deficient in settled population. These are :—

(i) Area north of Bindhachal ;

(ii) Area south of Bindhachal ;

(iii) Area north of the Railway line between Pahara and Jhingura station ;

(iv) Area south-east of Kachhwa.

Among these, the areas situated to the north of the Ganges, i. e., (i) and (ii), are without settled population owing to the danger of floods. Those to the south of the Ganges, i. e. (ii) and (iii), are infertile.

Mirzapur being the nodal point in this map, most of the lines of communication centre on it. A glance at the map will show that most of the lines of communication are in the western half of the map. This is to be expected from the fact that most of the population of the area is to be found in that part.

It is striking to note that railway communications are deficient in the area represented by this map. This is to be expected from the absence of many large towns in the area. Mirzapur and Bindhachal, the only big towns in the area, are close to each other and lie in the general direction followed by the main line of the East Indian Railway. If Bindhachal had not been in this general direction, it would have been necessary to build a branch line of the railway to connect it to Mirzapur. The existence of the Vindhyas in the south acts as a barrier for any railway line to approach from that direction.

The two railway lines that serve this area are (i) the East Indian Railway from Calcutta to Ghaziabad, and (ii) the Oudh and Tirhut Railway from Bhatni to Allahabad. The O & T. R. has also a short branch line to connect Mirzapur to the line going to Allahabad. The branch line stops at Mirzapur Ghat without crossing the river. Thus, a generalised picture of the railway communications on this map may be two parallel lines to serve the country on the two sides of the Ganges with a short branch almost connecting them near Mirzapur. It may be of interest to point out that the E. I. R. not only serves Mirzapur directly, but also the numerous quarries that lie near it, to the south of the Ganges The O. & T. R., on the other hand, serves the rich agricultural land to the north of the Ganges. A feature of the railway lines on this map is the long stretch of embankments on which they run. There are three stretches of the embankment on the E. I. R., the longest being between Pahara and Mirzapur, and the other two between Mirzapur and Bindhachal. In some cases the embankment is as much as 15 feet above the genaral level. A similarly long stretch of embankment marks the branch

line of the O. & T. R. A short stretch of embankment is also found on the O. & T. R. going to Allahabad.

There are some good roads in this area, but as mentioned above, these are mostly in the western half of the map. There are two first class roads, both running generally north-south. There is no first class road running east-west. The relative absence of towns is the chief explanation. These first class roads are (i) the Great Deccan Road, which comes to Mirzapur only to join the Grand Trunk Road lying to the north of this map, and (ii) the Mirzapur-Jaunpur Road which crosses the Grand Trunk Road. The Mirzapur-Jaunpur Road crosses the Ganges at Mirzapur by a Pontoon bridge which is dismantled during the rainy season.

There are a large number of second class metalled roads. They are also mostly in the most thickly populated area, the western half of the map. The most important of these second class roads are those connecting Mirzapur to Bindhachal and Mirzapur to Robertsganj. Several other second class roads have been built to serve the stone quarries in different parts of the map.

The effect of stone quarries on communications in this map is intimate. Thus, the road from Toswa Parsia to the bank of the Ganges is entirely for the benefit of the quarry near the Toswa Parsia, for this road passes practically through an uninhabited area. Similarly, the road from Jhingura, on the E. I. R., runs to the Vidhyas, crosses the Robertsganj Road and thence runs along the foot of the plateau and goes finally to Mirzapur by the Great Deccan Road. This road serves the largest number of quarries on this map.

The railway siding from Pahara, on the E. I. R., is also an example of the influence of stone quarrying on communications. It will be noticed from the map that stone quarries are generally located on the outer skirts of the plateau or on the foothills, which can be made easily accessible.

A number of unmetalled roads are also found on this map. The largest number of these radiate from Kachhwa which is a market town and serves the area far off from Mirzapur. The area near Kachhwa is not only far off from Mirzapur and separated by a wide bed of the Ganges, but is also a rich agricultural land. This can be seen from the large size of the villages.

Other unmetalled roads are continuation of the second class metalled roads only ; e.g., to Pandri Shivgarh or to the Tanda Falls and beyond to Sirsi.

A large number of tracks or footpaths cross the plateau region in all directions to serve the forest area for exploitation.

It is noticed that the areas deficient in population mentioned above, are also deficient in communication lines.

A minor feature of the map is the presence of a large number of lined wells. These wells abound in thickly populated areas. They, however, disappear from the areas in the neighbourhood of the Ganges, where water for domestic purpose can be drawn from the river, and in the plateau region where it is difficult to dig wells and where there is no settled population.

This map is typical of the Gangetic plain where it borders on the peninsular region of India. It provides an example of the plateau region as well as of the Gangetic plain. Agriculture, stone quarrying and forestry naturally rule the life of the people in such areas.

### EXERCISES ON SCALES

1. Construct a plane scale of 6 inches to 1 mile to show divisions of 100 yards and 500 yards.

2. Construct a plane scale for 1 inch to 1 mile showing suitable divisions in yards.

3. Construct a plane scale of 2 miles to 1 inch, showing sub-divisions into furlongs.

4. Construct a scale of 16 miles to 1 inch, showing quarter miles.

5. Construct a scale of 1/1,00,000 to show quarter miles.

6. Construct scale of 1/20,000 to show yards. Also add a scale of paces (standard pace of 30").

7. Construct a time scale for marching at 3 miles an hour for a map on the scale of 1/100,000.

8. Two bridges are exactly 3 miles distant from each other. On the map of the area they are shown to be 7·5 inches apart. Construct a graphical scale and also give the R. F. of the map.

9. Construct a time and distance scale for an aeroplane travelling at 120 miles per hour, using a map on the scale of 1/1,000,000 (1/M).

10. Which is on a larger scale : the one inch Survey of India map, or the French 1/50,000 map, or the German 1/80,000 map ?

11. Construct a scale of slopes for a map on 1/21,120 with a V. I. of 20 feet to show slopes up to 50°.

## EXERCISES ON MAP READING

1. Comment on the different methods by which relief is shown on the topographical maps.

2. What is a contour line ? Distinguish it from a form line. On what principle is the contour line based ?

3. How is relief on a map shown by the contour line ? Show by contours the following :

   (a) Spur, (b) Valley. (c) Watershed, (d) Hill, (e) Under-feature.

4. Define 'slope'. Classify slopes and show each class of slope by contour lines, adding sections under the contours for each slope.

5. What is gradient ? How is it calculated ? How will you convert a gradient into a slope in degrees of angle ? Give an example.

6. How will you determine the intervisibility between two points with the help of a contour map ? Illustrate by example.

7. What is a section ? What are its uses ? Draw an imaginary section illustrating the whole process.

8. Convert the following gradients into degrees of slopes :—

$$1/5, \quad 1/12, \quad \frac{1}{15}, \quad \frac{1}{20}, \quad \text{and} \quad \frac{1}{30},$$

9. Convert the following degrees of slope into gradients :—
   5°, 6°, 10°, and 15°.

10. On the Mirzapur sheet of the Survey of India map $(63\frac{K}{12})$ calculate the gradient of the road near Tanda Falls.

11. In Fig. 49 on page 80 ;

(a) Are X and Y intervisible ?

(b) What will be the probable course of a motor road ?

(c) Is X situated in a valley or on a spur ?

(d) Mark the courses of streams flowing to the north.

(e) Measure the slope between O and 50' contour, supposing that the scale of the map is 1/5,000.

# WEATHER MAP

A weather map shows the geographical distribution of weather elements from day to day, or from any one fixed period to another fixed period. It differs from the general or the topographical map in that the data shown in it are not fixed to any particular part of the map : they change from time to time. It is a special type of a map which shows only one type of geographical distribution, the weather. The importance of the weather map, however, has grown tremendously in the modern world. The day-to-day life of the modern society is regulated largely by the weather. Forecasts of the future weather have therefore, become a necessity. These forecasts, however, can be possible only with the help of the weather map. The weather map, thus, describes not only the kind of weather prevailing at any time in any part of the world, but is also the very basis of weather forecasts.

The Daily Weather Map usually gives information about winds, rainfall, and the distribution of air pressure by means of isobars. It does not show the distribution of temperature. Temperature distribution is shown only on climatic maps, not on weather maps. Unlike the changes in the barometer which shows the air pressure, the changes in the thermometer vary with the hour of the day or night rather than with the change in weather. They are therefore neglected in a weather map which emphasizes the isobaric rather than the isothermal distribution. Some weather maps give additional information about the amount of the cloudiness prevalent, and also about fog.

The weather elements are shown on the weather map by certain fixed sign which enjoy international recognition. These signs have been fixed by the International Meteorological Organisation which has its headquarters in Switzerland. (The organisation is known by the initial letters of the French words for it, viz., O. M. L.) The signs that are of use to us here given are below :—

### THE BEAUFORT LETTERS AND INTERNATIONAL SYMBOLS

**(1) Appearance of Sky.**

| | | |
|---|---|---|
| b | | Blue sky whether with clear or hazy atmosphere. |
| c | | Cloudy, i.e., detached opening clouds. |
| o | | Overcast, i.e., the whole sky covered with one impervious cloud. |
| g | | Gloom. |
| u | | Ugly, threatening sky. |

**(2) Wind**

| | | |
|---|---|---|
| q | | Squalls. |
| KQ | | Line squall. |

**(3) Precipitation.**

| | | |
|---|---|---|
| r | ● | Rain. |
| p | ▽ | Passing showers.* |
| d | , | Drizzle. |
| s | ✳ | Snow. |
| rs | ✳ | Sleet. |
| h | ▲ | Hail. |

**(4) Electrical Phenomena.**

| | | |
|---|---|---|
| t | | Thunder. |
| l | < | Distant lightning. |
| tl | ℞ | Thunderstorm. |

**(5) Atmospheric Obscurity and Water Vapour.**

| | | |
|---|---|---|
| f | ≡ | Fog     } Range of visibility less than 1,100 |
| fe | | Wet Fog } yards. |
| z | ∞ | Haze, range of visibility 1,100 yards or more, but less than 2,200 yards. |
| m | = | Mist, range of visibility 1,100 yards or more, but less than 2,200 yards. |
| v | ◊ | Unusual visibility of distant objects. |
| e | | Wet air, without rain falling. |
| y | | Dry air (less than 60 per cent humidity). |

**(6) Ground Phenomena.**

| | | |
|---|---|---|
| w | ⌂ | Dew. |
| x | ⊔ | Hoar-frost. |

Fig. 52

## THE BEAUFORT WIND SCALE.

| Beau-fort No. | Wind | Arrow. | Speed. m.p.h. | Commonly observed effects of corresponding winds. |
|---|---|---|---|---|
| 0 | Calm | ☉ | 0 | Calm, smoke rises vertically. |
| 1 | Light air | | 2 | Direction of wind shown by smoke drift, but not by wind vanes. |
| 2 | Light breeze | | 5 | Wind felt on face; leaves rustle, ordinary vane moved by wind. |
| 3 | Gentle breeze | | 10 | Leaves and small twigs in constant motion; wind extends light flag. |
| 4 | Moderate breeze | | 15 | Raises dust and loose paper; small branches are moved. |
| 5 | Fresh breeze | | 21 | Small trees in leaf begin to sway, crested wavelets form on inland waters. |
| 6 | Strong breeze | | 27 | Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty. |
| 7 | Moderate gale | | 35 | Whole trees in motion; inconvenience felt when walking against wind. |
| 8 | Fresh gale | | 42 | Breaks twigs off trees; generally impedes progress. |
| 9 | Strong gale | | 50 | Slight structural damage occurs (chimney pots and slates removed). |
| 10 | Whole gale | | 59 | Seldom experienced inland; trees uprooted; considerable structural damage occurs. |
| 11 | Storm | | 68 | Very rarely experienced; accompanied by widespread damage. |
| 12 | Hurricane | | above 75 | |

### Fig. 53

The velocity of the wind can also be determined by the following signs :—

Light winds: 2 to 5 miles per hour, moving leaves.

Moderate wind: 7 to 10 miles, moving branches.

Brisk wind: 18 miles to 20 miles per hour, swaying branches, blowing up dust.

High wind: 27 to 30 miles swaying trees, blowing up twigs.

Gale: 45 to 50 miles breaking branches.

Hurricane: 75 miles or more. Uprooting trees and pulling down structures.

Among the instruments used for taking observations of weather elements, the most important are :—

1. The Barometer.

2. The Anemometer.

3. The Rain Gauge.

4. The Thermometer.

There are two types of Barometers in use, one a mercury Barometer and the other a spring Barometer (also known as an aneroid). On page 34 is given a picture of an aneroid. The aneroid is a hollow box of metal from which most of the air has been excluded. There is a lid placed in such a way that it remains flexible. There is a spring kept inside the box to keep the lid in position which may be altered with change of air pressure on the lid. On the lid there is a lever with a needle to show the change of pressure being exerted on the lid. As the earth's gravity does not affect the aneroid, it is not necessary to make any correction for latitude for the readings.

The aneroid is convenient because the scale can be graduated to show pressure in millibars, or inched simultaneously.

The mercury Barometer is a glass tube with a column of mercury in it. The tube is graduated to measure the air pressure.

The air pressure is measured either in inches, or in millimeters, or in millibars. Millimeters are used only for scientific purposes in the laboratory. Inches are used commonly in the English-speaking countries. Millibars are used commonly on the Continent of Europe. Recently, Millibars are becoming popular even in the English-speaking countries because of the superiority of this system of measurement. A millibar is a unit of pressure. The name "millibar" implies that the unit is a thousandth part of a bar. The bar in the case of air pressure is a million
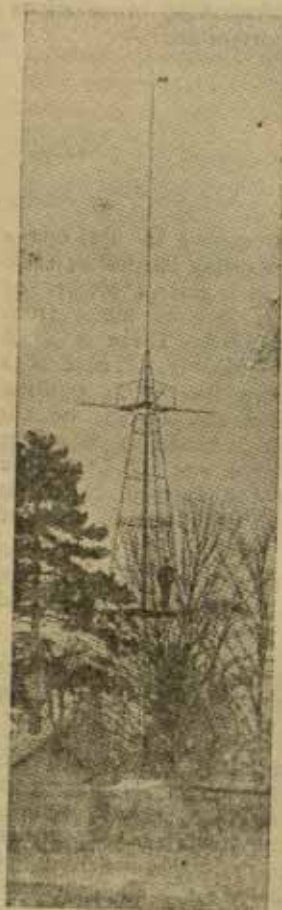
Fig 54 Anemometer.

times the unit of pressure on the centimeter gramme-second system. For our purposes it is enough to know that 1000 millibars correspond very nearly to 29½ inches, or 750 millimeter at standard temperature.

The anemometer records the direction and velocity of winds which pass its wind vane. The anemometer requires a very large open space for erection.

The observations about the direction of winds are presented as "wind roses". Wind roses show the prevalent direction of winds at a particular place for a certain period, or the general tendency of wind direction there. They do not therefore appear on weather maps.

Wind velocity, however, is recorded continuously and appears on every weather map by means of notches to an arrow which shows the direction of wind at a particular hour for a particular place.

The Thermometer records temperature in shade. There are several types of thermometers according to the scale of measurement used ; e. g., the Fahrenheit, Centigrade, Reaumur and Absolute.

The scale of the Fahrenheit thermometer is divided into 212 degrees, that of the Reaumur into 80 degrees, of Centigrade into 100 degrees and of Absolute into 373 degrees. The reading in the Centigrade scale with 273 added is called absolute temperature. The absolute temperature is mentioned as "tt" without the addition of the sign of a degree.



Fig. 55  Maximum and Minimum Thermometer.

The Barometer, the Thermometer and the Anemometer are sometimes provided with an automatic arrangement for self-recording or automatic recording of the observa-
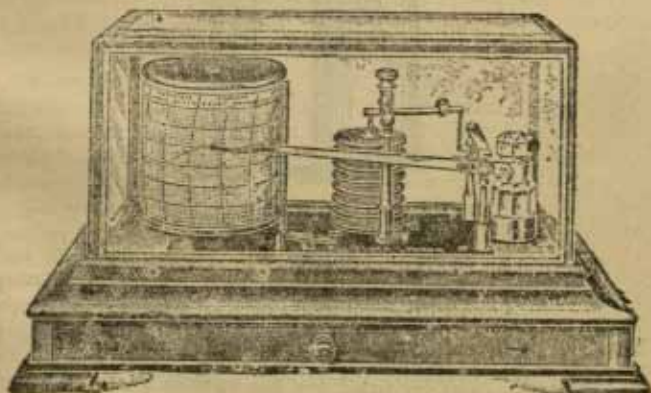


Fig. 56 Barograph.

tions by the instrument itself, without the help of anybody.
The continuous records so obtained are known the Baro-
graph, the Thermograph, and the Anemograph respectively
for the above named instruments.

Rainfall is recorded by means of a Rain Gauge. There
are many varieties of rain gauges, but the principle under-
lying them all is the same, *i.e.*, to collect all the rain that
falls on a known area, and store it in such a way that there
is no loss by evaporation. In the following diagram a rain
gauge is shown. It has a metal cylinder, in which a
funnel is fitted accurately so that it directs the rain to a
receiving bottle. The graduated jar used to measure the
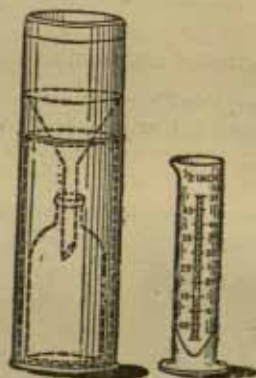amount of rain has a fixed ratio in area with the cylinder.



Fig. 57    Rain gauge.

There is an intimate relation between air pressure and
weather. Drawing of isobars from the weather information
supplied from the different observation stations is there-
fore the most important part of making and interpreting
a weather map. Wind direction, wind velocity and the
actual air pressure recorded for the various stations deter-
mine the actual direction of the isobars on the weather
map. Isobars are the lines of equal air pressure, so that

all the places having the same air pressure should be joined together by the same isobar. Before the readings of air pressure for the various stations are entered on the weather map, they are converted into the sea-level air pressure. The isobars join the stations showing these reduced air pressure figures In India, the general practice is to issue readings that have already been corrected in this way.

According to Buys Ballot's Law, the winds blow almost parallel to the isobars keeping the lower pressure to their left. This will help in fixing the direction of the isobars on the weather map.

Greater velocity of wind always signifies the closeness of isobars. Several isobars should be crowded together therefore in those areas of the map where the wind velocity is considerable.

When the isobars are drawn over a weather map for a large area, it is better to draw the isobars in those regions where the analysis is simple. The isobars should be drawn in such a way that when they have to pass between two places they should pass as near a particular station as its air pressure record would justify. Thus the isobar of, say 29 inches, while passing between two places having air pressure of 27 inches and 30 inches respectively, should be placed nearer the place with 30 inches than to the other having 27 inches.

When the isobars have been completed, it becomes necessary to mark the Fronts on the weather map. The warm fronts are shown by a line of half circles, and cold fronts by a line of black teeth pointing towards the warm sector.

Temperatures may then be shown, if desired, on the weather map in degrees. Rainfall and other data are shown by their proper signs.

The following diagram gives the international signs and method of recording weather data for each station appearing on the weather map.

It is to be noted in the above diagram that the air pressure is shown by figures which are to be added to

1000 to get the correct number of millibars. Sometimes, even the decimal point is dropped, so that the last digit has to be considered as a decimal point. In American maps, temperature appears in F. degrees on the right of the arrow.
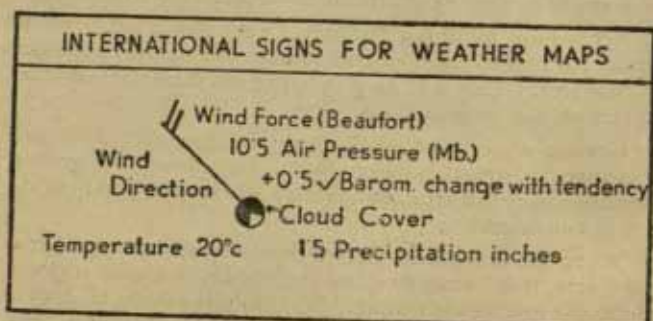


Fig. 58 International weather signs.

### WEATHER ANALYSIS

The isobars drawn on the weather map get arranged in various ways. There are three main shapes of the isobars noticeable on the weather maps generally. These are :—

1. Cyclones ;
2. Anti-cyclones ; and
3. Cols.

The cyclones are the closed isobars with *decreasing* pressure towards the centre. The anti-cyclone is composed of closed isobars with *increasing* pressure towards the centre. The cyclones and the anti-cyclones are known as "Lows" and "Highs" respectively, because of the low pressure and the high pressure towards the centre.

The col is the combination of two wedges and two troughs separating "Lows" and "Highs."

But the passage from one shape to the other is marked by other minor shapes of isobars which are generally associated with special types of weather.

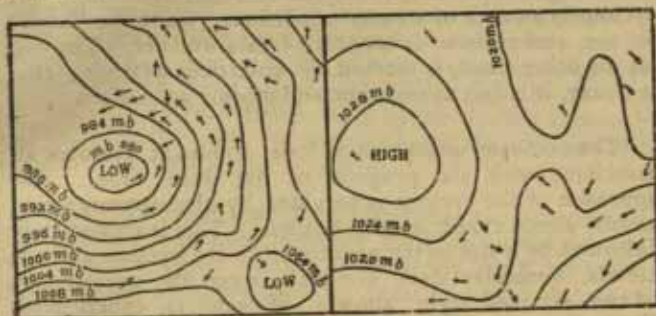The following figures show the shapes under discussion :—



Fig. 59.  Cyclone.          Fig. 60.  Anti-cyclone.
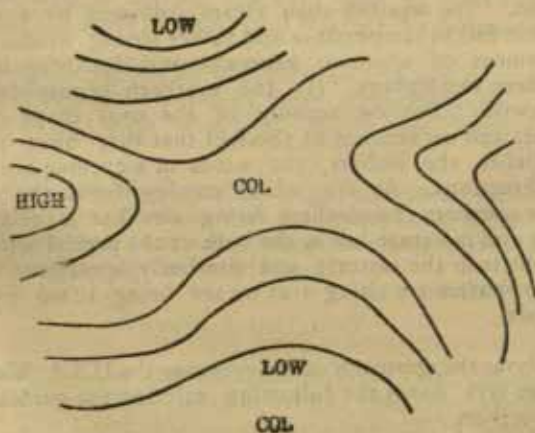


Fig. 61.

These characteristic arrangements of isobars on a weather map are associated with special types of weather. This weather changes as the arrangement of isobars changes, owing to the change in the air pressure.

As a generalisation, it may be said that the "low" or cyclone is an area of stormy conditions, while the "high" or the anti-cyclone is an area of fair weather. The col, on the other hand, is marked by unsettled weather ; that is to say, it is fair at one time and stormy soon after.

The cyclonic weather has four dominant features all associated with the progress of the warm front. The approach of the cyclone is heralded by the appearance of woolly cirrus clouds on the horizon   This is immediately followed by a rise in temperature. As the cyclone arrives, clouds, generally dark nimbus, cover the greater part of the sky and light shower of rain is experienced. Gradually, as the cyclone moves onward on its path, the clouds break and there is some fall in temperature.  This brief dry weather is followed by a fairly heavy shower of rain.  The weather then clears followed by a considerable fall in temperature and rather strong winds.  The movement of winds is generally anti-clockwise in the northern hemisphere.  (In the southern hemisphere it is clockwise).  But on account of the oval shape of t e isobars and on account of the fact that they blow nearly parallel to the isobars, the winds in a cyclone are from all directions.  As the winds coming from the south in the northern hemisphere bring air that is relatively warm and moisture-laden, the bulk of the precipitation in a cyclone is in the easterly and southerly quadrants where the air masses are rising over or are being lifted by, the cold air.

About the approach of the cyclones the U.S.A  Weather Bureau lays down the following  rule for the guidance of its observers :—

"When  the wind  sets in from  points between south

and south-east and the barometer falls steadily, a storm is approaching from the west or north-west, and its centre will pass near or north of the observer within 12 to 24 hours, with wind shifting to north-west way of south-west and west. When the wind sets in from points between east and north-east and the barometer falls steadily, a storm is approaching from the south or south-west and its centre will pass near or to the south or east of the observer within 12 to 24 hours, with wind shifting to north-west by way of north. The rapidity of the storm's approach and its intensity will be indicated by the rate and the amount of the fall in the barometer."

There is a rule that like attracts like. Big areas of clear and relatively cool weather tend to move toward other similar areas, known as areas of high pressure. Storm areas, or those of low pressure, tend to move toward other similar areas. As a rule, the northern latitudes experience chronic low pressure, and the latitudes of the southern border (in U.S.A.) equally chronic high pressure. Storms moving eastward tend to veer to the north, and the areas of clear, cool weather, to the south.

The weather associated with an anti-cyclone is generally dry. This does not necessarily mean a cloudless sky. In fact, cloud is quite common. Winds are light and variable.

Anti-cyclones show little energy and therefore they often remain over the same area for a very long time. It is for this reason that cold waves or heat waves are associated often with the anti-cyclones.

### WEATHER FORECASTING

The study of the weather conditions of the different parts of the world leads us to conclude that "the weather travels." This conclusion encourages scientists to forecast the weather of the future. For a successful forecast, however, it is necessary not only to understand fully the

working of the laws of atmosphere, but also to know the local weather conditions as well as the weather conditions prevailing at that time in the surrounding area. This knowledge of the "local" and the "foreign" weather during a particular period and at a particular point of time should be as complete as possible.

It must have been noticed that the resulting weather is really the product of the isobaric arrangement. The arrangement of the isobars is closely related to the passage of cyclones and anti-cyclones. So that if one can forecast correctly the path of progress and the development of these, one can forecast correctly the weather that an area is likely to have in the coming future.

"The central problem of forecasting weather is that of forecasting the future development of the distribution of pressure, which usually means the forecasting of the development and motion of cyclonic depressions."

The knowledge of the "local" weather is supplied to the forecaster by the Daily Weather Report. The knowledge of the "foreign weather" is supplied by the "synoptic charts" that are prepared from data communicated from the surrounding areas. The forecaster generally makes use of "synchronous charts" which are the synoptic charts for a large surrounding area prepared from the weather prevailing all over that area at the same point of time. "Isallobaric" charts showing the change of pressure during the last twenty-four hours over the area are also made use of in forecasting of weather. This change points to the direction in which the weather-producing factors, that is to say, the "highs" or "lows" are moving.

The following figures give examples of isobar drawing :—

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* D. Brunt : Meteorolgy, Page 79.

Fig. 62



Fig. 63

Before drawing the isobars, a little study of the chart would reveal that (1) air pressure is high and increasing towards the bottom of the chart : (2) there must therefore be a 'High' there. This is also indicated by the clockwise direction of the winds. The gentle speed of winds also supports that conclusion. (3) The anti-clockwise wind direction and pressure distribution similarly mark out a cyclone or a 'low' towards the left-hand corner. Another 'low' is similarly shown towards the right-hand corner.

In drawing the isobars the above points must be borne in mind. The spacing of the isobars will be regulated by the velocity of winds. The higher velocity to the south of the 'Low' must bring the isobars close together.

The places having the same pressure as that of the isobars selected to be drawn must be joined by the proper isobar. The other isobars would pass leaving the places with lower or higher value outside or inside the enclosure that they make.

Before a weather map can be analysed successfully, it becomes necessary to draw the warm and cold fronts of any cyclone that may appear on it. The important thing to remember in drawing the fronts is that the isobars are more or less straight within the warm sector enclosed between the cold front and the warm front. Help is also afforded by the shift of wind direction. Considering these things, we have drawn the necessary fronts for the cyclone in the preceding weather map in the following diagram :
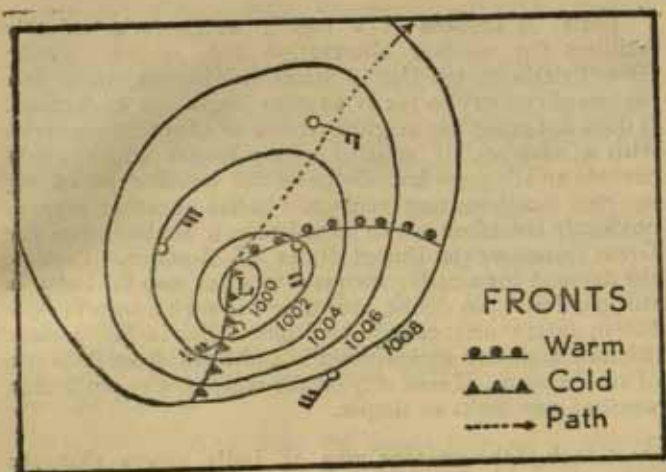
Fig. 64

#### INDIAN WEATHER REPORTS

The weather map for India does not provide much weather information. The weather map here gives information about the pressure distribution, wind direction and wind velocity, and rainfall. There are two other maps printed under the main map which show the change in pressure and the change in temperature during the previous twenty-four hours for the different parts of India. A few tables are also appended to the map which record temperature, humidity, cloud and other weather information. This latter information is not plotted on the map. Thus, the Indian weather map shows in a plotted form only part of the weather data contained in the tables appended to it. The salient features of the Indian weather during the previous twenty-four hours are described in a summary, giving information about the different climatic provinces of India. A forecast for the country as a whole is also given.

India is situated in a region which lacks suitable facilities for weather observation and record. Unlike Great Britain or the United States of America, India is a backward country so far as weather maps are concerned. It does not enjoy the neighbourhood of advanced countries with a network of weather observatories which could provide an adequate knowledge of the weather prevailing in the neighbouring regions. Indian weather map is obviously therefore not so complete as a similar map for Great Britain or the United States of America. Besides, the demand for a really adequate weather map in India is still not felt. No doubt, the value for such a map for the Indian agriculturist cannot be denied. But in his present illiterate state the agriculturist in India can make little use of such a map. These may be the reasons why the Indian weather map looks so simple.

A look at the weather map of India shows that the isobars are seldom smooth for long distances. They are marked by a good deal of curving or sinuosity. This sinuosity is marked greatly during the rainy season. Another feature of this map is that the winter and summer maps are greatly dissimilar.

The winter weather map is marked generally by "wedges" of high pressure which extend from the 'Highs' situated somewhere in the north-west of India. These wedges are very extensive and dominate the weather conditions not only in the Indo-Gangetic Basin, but also over the Peninsula.

Sometimes, clearly marked anti-cyclones develop, specially in the Peninsula, to accentuate the anti-cyclonic weather produced by the wedges mentioned above.

The monotony of these wedges is broken sometimes by the appearance of depressions in the north-western part of the country. These depressions move either towards Kashmir and the Western Himalayas, or towards Assam through the Indo-Gangetic Valley. These dep-

ressions introduce a certain amount of cyclonic weather in India.

The summer weather map of India is marked by the occurence of a "trough" of low pressure somewhere in the north-west. The flow of air from the sea is influenced by the presence of this trough. This fact causes a widespread rainfall all over the country.

Now and then, a few 'Highs' or the wedges of 'Highs' also appear in the north-west, or even in the interior of the country. These produce generally dry weather.

Autumns, and spring weather maps are characterised by a number of storms, either 'Highs,' or 'Lows'. They appear both in the Indo-Gangetic Valley as well as in the Peninsula. They are associated with a good deal of unsettled weather.

It is to be noticed that the appearance of a clearly marked 'High', during winter produces a very cold weather. During summer, however, it produces very hot temperatures.

During the rainy season, a few depressions or cyclones develop at the head of the Bay of Bengal. They generally move towards the trough of low pressure still existing in the north-west of the country.

The following figures 65, 66 and 67 give examples of some types of Indian weather maps. They show only such typical conditions as usually occur at the time of the year for which the maps have been drawn. These are not actual maps for any particular day. Actual weather maps should be obtained from the Meteorological Department of the Government of India and consulted for the sake of practice in reading a weather map.

The most outstanding type of weather is that of the rainy season, typified by the weather conditions prevailing during the month of July. The monsoon rains are received over most of the country then, following a very trying summer weather. The rain-giving monsoon is often

described, while describing the monsoon weather, as 'vigorous,' 'strong' and 'active'. These three words associate a definite quantitative value of rainfall. When the rainfall is usually about 2 inches or more at a particular place the monsoon is said to be 'vigorous.' When the amount of rain is about 1 to 2 inches, the monsoon is said to be 'strong.' But when the rainfall is less than 1 inch the monsoon is described as active. It must, however, be remembered that for a place which usually gets a high rainfall the word "vigorous" would be applied for the monsoon only when the rainfall is very heavy.
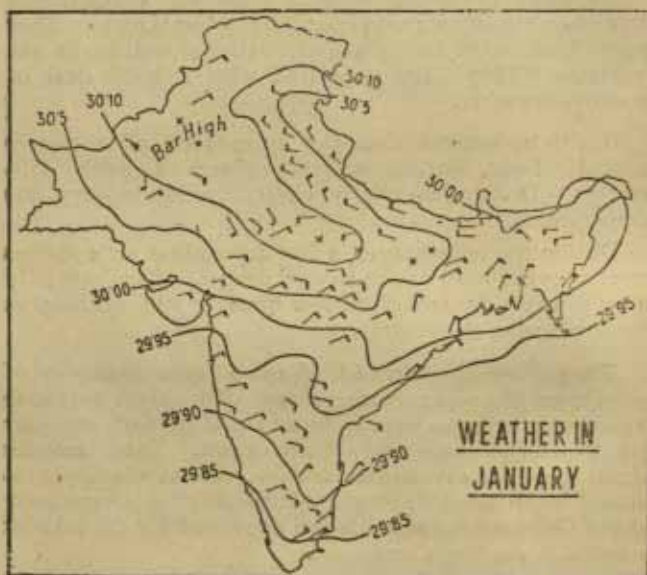


Fig. 65

Apart from the trough of low pressure mentioned in the preceding pages, and the depression, the important

thing that strikes us in the rainy season weather map of
India is the closeness of the isobars, specially in the south.
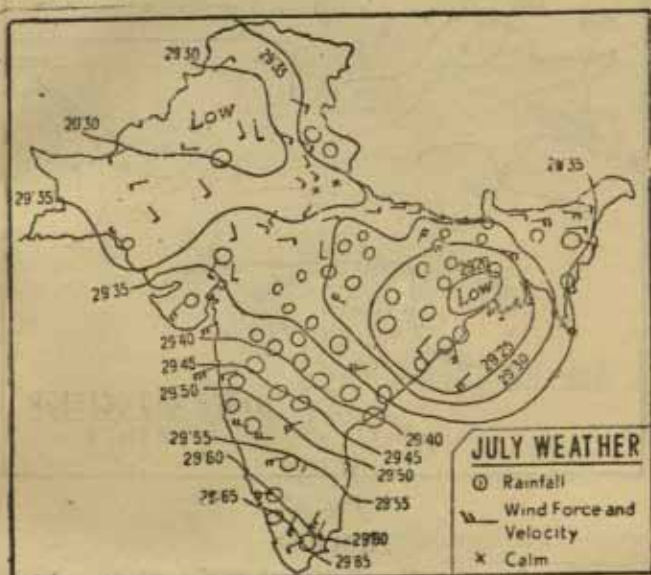This affects the wind force as well as the distribution
of rainfall.



Fig. 66
TABLE 1
*Barometer Inches Converted to Millibars*

| Inches | Millibars | Inches | Millibars |
|--------|-----------|--------|-----------|
| 29 | 982·1 | 30 | 1015·9 |
| ·1 | 985·4 | ·1 | 1019·3 |
| ·2 | 988·8 | ·2 | 1022·7 |
| ·3 | 992·2 | ·3 | 1026·1 |
| ·4 | 995·6 | ·4 | 1029·5 |
| ·5 | 999·0 | ·5 | 1032·9 |
| ·6 | 1002·0 | ·6 | 1036·2 |
| ·7 | 1005·8 | ·7 | 1039·6 |
| 8 | 1009·1 | ·8 | 1043·3 |
| ·9 | 1012·5 | ·9 | 1046·4 |
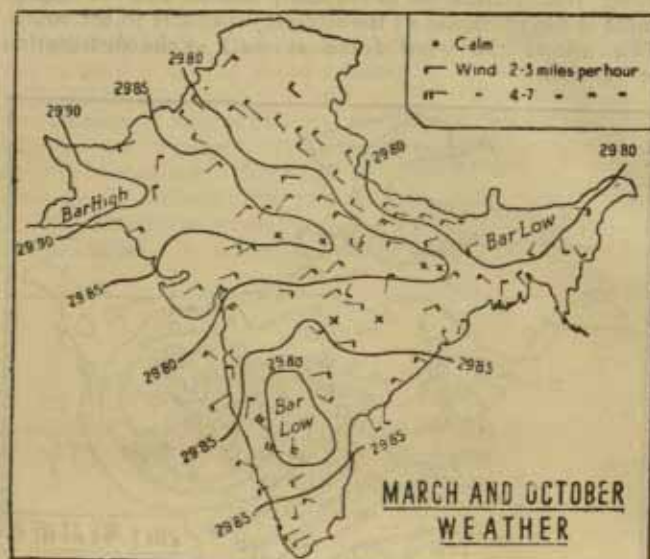
Fig. 67

## TABLE II

*Conversion from Centigrade to Fahrenheit*

| °C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| — 0 | 32 | 30·2 | 28·4 | 26·6 | 24·8 | 23 | 21·2 | 19·4 | 17·6 | 15·8 |
| —10 | 14 | 12·2 | 10·4 | 8·6 | 6·8 | 5 | 3·2 | 9·4 | —0·4 | —2·2 |
| —20 | —4·0 | —5·8 | —7·6 | —9·4 | —11·2 | —13 | —14·8 | —16·6 | —18·4 | —20·2 |
| + 0 | 32 | 33·8 | 35·6 | 37·4 | 39·2 | 41 | 42·8 | 44·6 | 46·4 | 48·2 |
| +10 | 50 | 51·8 | 53·6 | 55·4 | 57·2 | 59 | 60·8 | 62·6 | 64·4 | 66·2 |
| +20 | 68 | 69·8 | 71·6 | 73·4 | 75·2 | 77 | 78·8 | 80·6 | 82·4 | 84·2 |
| +30 | 86 | 87·8 | 89·6 | 91·4 | 93·2 | 95 | 96·8 | 98·6 | 100·4 | 102·2 |
| +40 | 104 | 105·8 | 107·6 | 109·4 | 111·2 | 113 | 114·8 | 116·6 | 118·4 | 120·2 |

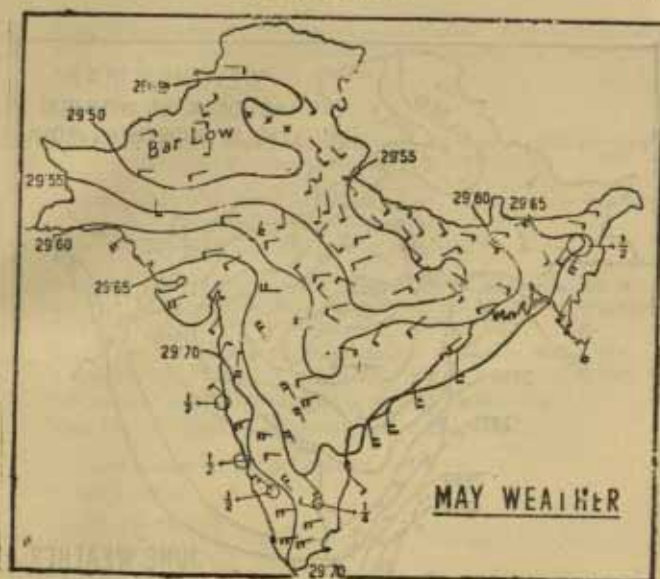[From Petterssen : Introduction to Meteorology, Page 229.]

Fig. 68

TABLE III
*Geostrophic Wind Velocity. (Miles Per Hour)*

| Latitude | Miles between consecutive isobars indicating pressure gradient. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 60 | 80 | 100 |
| Equator ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 10° | ... | ... | ... | ... | ... | ... | ... | 147 | 110 | 88 |
| 20° | ... | ... | 149 | 128 | 112 | 90 | 89 | 74 | 56 | 45 |
| 30° | ... | 122 | 102 | 87 | 76 | 68 | 61 | 51 | 38 | 30 |
| 40° | 119 | 95 | 79 | 69 | 59 | 53 | 48 | 40 | 30 | 24 |
| 50° | 100 | 80 | 66 | 57 | 50 | 44 | 40 | 33 | 25 | 20 |
| 60° | 88 | 71 | 59 | 50 | 44 | 39 | 35 | 29 | 22 | 18 |
| 70° | 81 | 65 | 54 | 46 | 41 | 36 | 32 | 27 | 20 | 16 |
| 80° | 78 | 62 | 52 | 41 | 39 | 34 | 31 | 26 | 19 | 16 |

WEATHER MAP
ASSOCIATED WITH HOT
LOO IN NORTHERN INDIA

Low

JUNE WEATHER
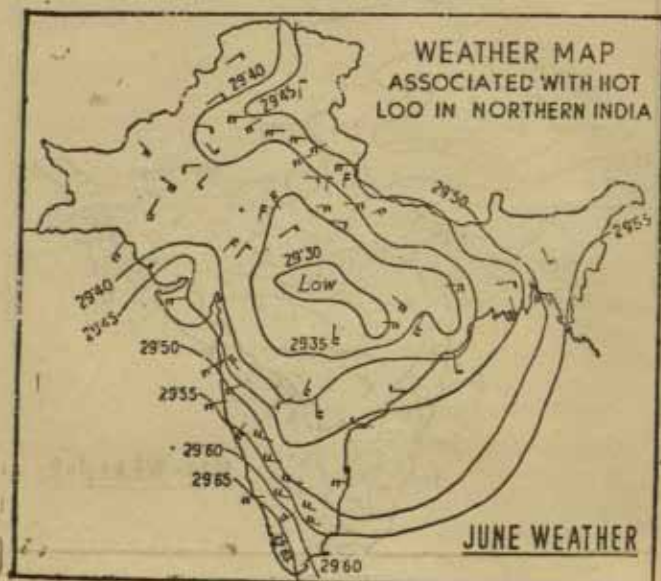
Fig. 69

## TABLE IV

Centigrade Equivalents of Some °F.

| 86°F | 30°C |
|------|------|
| 68°F | 20°C |
| 50°F | 10°C |
| 41°F | 5°C |

### EXERCISES ON WEATHER MAPS

1. What are isobars, and how are they drawn on maps ?  Explain how we can estimate roughly the direction and velocity of winds for a map showing isobars.

2. Describe the weather that may be experienced in the western part of the United Provinces when (a) a depression covers Central Provinces during the month of June, (b) an anti-cyclone covers Orissa during July.

3. What is meant by the pressure of atmosphere ? How is it measured ? Explain how the pressure distribution over a certain area helps to forecast its future weather.

4. What weather is to be expected :

   (a) when the wind is backing from the westward to the southward and the barometer has begun to fall ?

   (b) when the wind is veering from southward to westward and the barometer has begun to rise ?

5. How will you determine the path of a cyclone ?

6. Describe the weather that will be experienced in the Punjab when a "Bar High" with isobars closely crowded to get her appears at Quetta on its path towards the western Himalayas.

7. Why are the readings of the thermometer generally disregarded on a weather map ? How is temperature shown on a weather map ?

8. Describe the procedure adopted in weather forecasting.

9. What kind of weather is generally associated with :

   (a) a trough of low pressure ;

   (b) a wedge ;

   (c) a secondary ;

   (d) an anti-cyclone ?

10. Describe the weather that generally occurs ;

   (a) in the Central provinces in October or March ;

   (b) in Bengal in July ;

   (c) in United Provinces in May ;

   (d) in Peninsular India in January ;

   Give the illustrative weather maps for the above.

# MAP PROJECTIONS

The earth is a sphere and therefore the only true representation of it is the globe. For practical purposes, however, the globe is useless, as any globe made on a large scale is too big to handle. If the globe were to be made on the scale of the International or the Millionth map, (1/M. about 15·8 miles to the inch; not a very large scale) its diameter will have to be approximately 42 feet! How many of us can carry a globe of this dimension? Besides this difficulty of handing large globes, which alone can be of practical use; distances cannot be measured conveniently nor different regions compared on the globe. On account of these difficulties, for practical purposes the globe has to be discarded. Some methods for representing the sphere (the shape of the earth) on a plane surface (the flat map) have therefore to be found out. These methods are the map projections.

The word 'projection' here has been derived from geometry meaning that a particular geometrical shape is 'projected,' with the help of light as in a cinema, by throwing its shadow on a flat surface. In this way certain outlines are obtained on the flat surface. The character of these outlines naturally depends upon the position of the light in relation to the body to be projected. The projection may not be made sometimes directly on a flat surface, but on another geometrical figure which has a 'developable surface,' like that of a cone or cylinder. A 'developable surface' is one that can be spread flat by cutting open. Fig. 7o shows two such surfaces, the cone and the cylinder.

In order to remove some of the defects in the outlines, or the shadow picture, that may be thrown on the plane surface by the above method, help is taken from mathe-
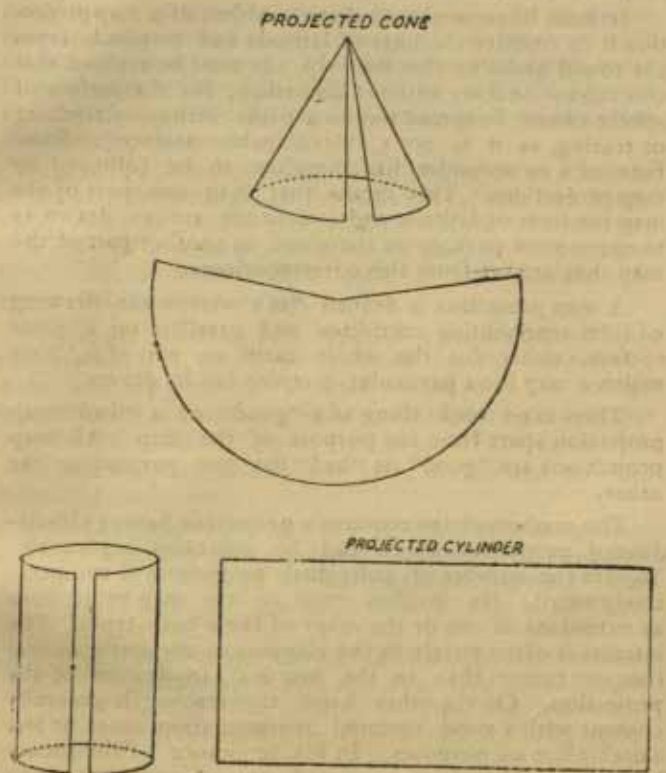


PROJECTED CONE

PROJECTED CYLINDER

Fig. 70.

matical calculations about the earth. Thus, the 'geometrical projection' has always to be *modified* by 'mathematical

projection' to give a satisfactory result. In practice
therefor the globe is *never projected with the help of light to
produce the network of a map.* The network is drawn by the
help of mathematical tables.

It must be remembered that the object of a map projec-
tion is to transfer the lines of latitude and longitude from
the round globe to that flat map. It must be realised that
this cannot be done without distortion ; for the surface of
sphere cannot be spread out on a plane without stretching
or tearing, as it is not a "developable surface". Some
form of a compromise has therefore to be followed by
map projections. This means that if in one part of the
map the lines of latitude and longtitude are so drawn as
to correspond to those on the globe, in another part of the
map they are far from this correspondence.

A map projection is defined "as a systematic drawing
of lines representing meridians and parallels on a plane
surface, either for the whole earth or part of it,"* on
which a map for a particular purpose can be drawn.

There is no such thing as a "good" or a "bad" map
projection apart from the purpose of the map. All map
projections are "good" or "bad" for one purpose or the
other.

The mathematician requires a projection having clearly-
defined properties which can be expressed rigorously.
To him the number of individual projections is compara-
tively small. He classifies most of the map projections
as variations of one or the other of these basic types. His
interest is often purely in the elegance of the mathematical
concept rather than in the practical application of the
projection. On the other hand, the teacher is generally
content with a good pictorial representation, more or less
suitable for all purposes. In his ignorance of the theory
he will often acclaim as a good general map even one
drawn on Mercator's projection which is misleading in
almost every respect if its properties are not understood.

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*Elements of Map Projection by Deetz and Adams.

It is the professional geographer who takes the middle course. He realises that there is probably a "best" map for illustrating any particular set of conditions. Sometimes he requires the property of equal area, at other times, the property of conformality. Sometimes he wishes his map to be centred at a particular place, on the earth's surface, at another time he wishes to emphasize some other quality in his map. His needs are many and varied and therefore he dislikes the limitation or standardisation of his map projections.

There can be hundreds of map projections or methods of drawing the network of the lines of latitude and longitude, every one having a special feature of its own. It is not quite accurate therefore to *classify* map projections. But from the student's point of view classification always helps understanding.

There are generally two types of classification of map projections; the first type is based on the *purpose* for which the map projection is best suited, and the second type is based on the method of *construction* of the map projection.

The first type divides the map projections into the following classes :—

(i) *Equal Area* or the Homolorgraphic projections. This class of projections shows correctly the areas of the earth on the map. The scale on this projection is true in all directions.

(ii) True shape or the *Orthomorphic* projections. [This class is also known as conformal Projections.] The outlines of countries are accurately shown on this projection. In order to achieve this, however, the scale is changed constantly. But the angles at which the meridians cut the parallels are everywhere right angles on this projection.

(iii) True Direction or the *Azimuthal* projections. The special feature of these projections is

that the azimuth ; that is the directions of all
points on the map as seen from a central
point on it are the same as the corresponding
directions on the surface of the earth.   It
must be remembered that the directions are
true only between the central point and those
seen from it ;   they are not necessarily true
between other points.  To distinguish between
an equal area projection and conformal pro-
jection just by looking at it, one should
remember that in an equal area projection
the distance between the parallels becomes
increasingly l ss in opposite directions from
the standard parallel or towards the poles.
In conformal projection this distance becomes
increasingly greater.

In the azimuthal projections the parallels are drawn as
complete circles.

The second type of classifica ion divides productions
into the following classes :—

(i) *Zenithal Projections*.  The method of their cons-
truction is derived from the supposition that
a part of the globe is 'projected' on a tangent
plane.

This c'ass is further subdivided into two classes :—

(a) according to the point where the tan-
gent plane is supposed to touch the
globe ; *i. e*, at the *pole*, the *equator* or
any *other point*.  This gives the three
classes in the same order :—

1.   The Polar Zenithal ;

2.   The Equatorial Zenithal;

3.   The Oblique Zenithal.

(b) according to the position from which the light
is supposed to be thrown, *i.e.*, from the *centr*
of the globe, the *diameter* of the globe or from
beyond the globe, at *infinity*.

This gives the three classes in the same order :

1. Gnomonic ;
2. Stereographic ;
3. Orthographic.

(ii) *Conical Projections.* The method of their construction is derived from the supposition that a certain part of the globe is projected on to the surface of a cone that is put round it. The cone is then supposed to be cut open and spread flat like a plane. The part of the globe which the enveloping cone is supposed to touch gives the starting point in the construction of the projection. The line along which the cone is supposed to touch the globe is called the STANDARD PARALLEL The line along which the cone is supposed to be cut open from the base to the apex is called the CENTRAL MERIDIAN.

(iii) *Cylindrical Projections.* When the globe is supposed to be covered by a cylinder, instead of a cone, the projection derived is a cyclindrical projection.

*Conventional Projections.* When the construction of a projection is derived analytically, not based on the 'projection' of the globe on a plane, a cone, or a cylinder it gives a conventional projection.

In discussing the construction and utility of some of the most common projections in use, we shall follow the second classification given above.

In order to grasp thoroughly the graphical construction of projections as described in the following pages, it is important to realise that a circle representing the earth on the selected scale is the first step. The circle represents the reduced earth, and gives the measurements for subsequent steps. These measurements are the following :—

(i) Radius of the standard parallel ;

(ii) Spacing of the parallels, for dividing the central meridian ;

(iii) Spacing of the meridians, for dividing the standard parallel.

The circle to represent the earth is drawn with a radius that is obtained with the help of the scale given for the map projection. This scale is called the equatorial scale, meaning that the ratio mentioned in scale is true for the equator. The radius of the earth is about 250 million inches. In order to get the radius (R) one has to *multiply the scale given by 250 million*. The result gives the radius in inches of the circle to be drawn.

Thus, for example, if the scale given is 1/10,000 (10 million), the R will be 1/10,000,000 by 250,000,000 ; *i.e.*, 25 inches. If the scale given is 1/125 millions, the multiplication by 250 millions will give the R of 2 inches. The following table is given for convenience :—

| Scale : R. F. | | Miles to Inch | R (inch) |
|---|---|---|---|
| 1 : 250 million | | 4000 | 1 |
| 1 : 200 | ,, | 3200 | 1¼ |
| 1 : 180 | ,, | 2880 | 1·4 |
| 1 : 125 | ,, | 2000 | 2 |
| 1 : 100 | ,, | 1600 | 2·5 |
| 1 : 75 | ,, | 1200 | 3⅓ |
| 1 : 60 | ,, | 960 | 4·1 |
| 1 : 50 | ,, | 800 | 5 |
| 1 : 40 | ,, | 640 | 6¼ |
| 1 : 2 | ,, | 32 | 25 |
| 1 : 1 | ,, | 16 | 250 |

It will be noticed from the table that the circle cannot be drawn conveniently for scales larger than 1 : 50 million. The graphic method is therefore unsuited for such scales. Even with trignometrical (mathematical)

method these scales are not convenient for exercises for students without proper equipment to draw parallels with large radii.

In map projection the capital R stands for the equatorial radius of the earth, and the small r stands for the radius of the standard parallel.

[For a comparison of some of the map projections, see Fig. 91 ahead.]

### ZENITHAL PROJECTIONS

Among the zenithal projections the most commonly used is the Gnomonic. The stereographic and the orthographic projections of this class were also common until recently. They have been, more or less, discarded now.

### GNOMONIC PROJECTION

When a plane is supposed to touch the globe at a point and the light is thrown from the centre, the projection that results is described as Gnomonic Projection. The most important properties of this projection are :—

(i) All Great Circles are represented by straight lines on this projection. A straight line drawn between any two points on a chart of this projection represents therefore the shortest distance or the most direct route between them.

(ii) All azimuths or directions from the centre of the map on this projection are correct.

(iii) In the case of the Polar Gnomonic Projection, (i.e., when the pole is the centre of the map) the meridians are straight lines radiating from the centre, and the parallels are concentric circles. In the case of the Equatorial Gnomonic, the parallels are curves except the equator which is a straight line.

(iv) The concentric circles representing the parallels become wider apart as the distance from

the pole or the centre of the map increases.
This causes the scale of the map to be greatly
exaggerated towards the outer boundaries of
the map. This exaggeration increases more
rapidly in the case of the meridians than in
the case of the parallels. Thus, in the case of
the Polar Gnomonic, for example, the exaggera-
tion of scale is as follows:—

|              | Latitude scale | Longitude scale |
|--------------|----------------|-----------------|
| At 80° Lat.  | 3 p. c.        | 1·15 p. c.      |
| „ 60° „       | 33 „           | 15·4 „          |

Owing to this exaggeration of scale outwards, places
near the boundary of the map become greatly distorted
in distances, areas and shapes.

(v) This projection cannot be used for making the
map of a complete hemisphere, as the lines
drawn for projecting points 90' distant from
the centre of the map become parallel of the
plane of projection. Such linns therefore can
never touch the plane of projection on which
the map is to be drawn.

(vi) It requires a good deal of computation and its
construction is difficult, except in the polar
case.

To construct the Polar Gnomonic Projection choose
the scale on which the map is to be drawn. With that
scale as the radius, draw a circle. From the centre of
this circle, starting from the side of the polar axis, draw
radii at angles which are *complements* of those of the
latitudes desired to be shown. Thus, if the latitudes to
be shown are 80', 70°, 60° and 50' then the radii will be
drawn at the angles of 10 , 20°, 30', and 40"; all these
angles being complementary to those of the latitudes. If
desired, the radii can be drawn at the angles representing
the latitudes, but the angles in this case will have to be
measured from the side of the equator and not from the
side of the polar axis.

Produce these radii to meet a straight line drawn tangent to the pole on this circle.

With this pole as the centre and the distance marked by the produced radii as radius, draw semi-circles to represent the latitudes.

From this centre lay off the required longitudes with the help of a protractor.

Rub off the first circle and its radii and complete the circles of the projection.
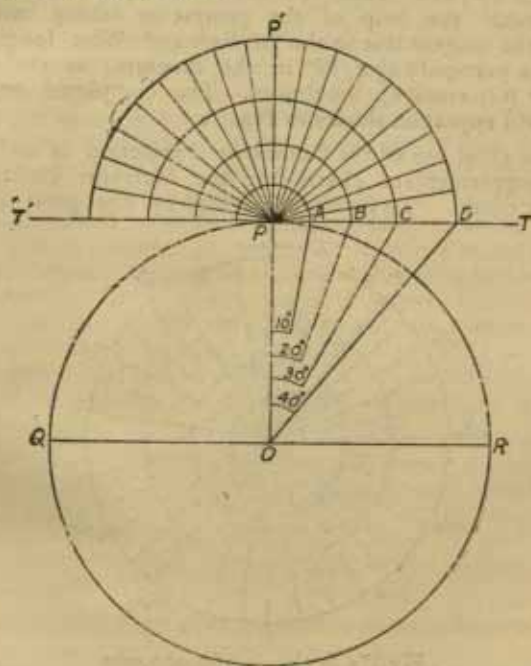


Fig. 71

In Fig. 70 we select a scale of 1/160,000,000 or 1 inch is equal roughly to 2525 miles. On this scale the radius

of the earth will be represented by about 1·56 inch.
With this radius therefore we describe the circle QPR
from the centre O. We decide to show on the projection
the latitudes of 80°, 70°, 60°, and 50°. We draw radii
therefore from O making with the polar axis the angles
of 10°, 20°, 30° and 40°. Now, we produce them to
touch the tangent plane TT' at A, B, C, and D. With P
as the centre and PA, PB, PC and PD respectively and
radii, draw semi-circles representing the latitudes of 80°,
70°, and 60°, etc. From the centre P lay off the longi-
tudes with the help of the protractor taking care to
mark the tangent line as the 90° East and West longitude
and the perpendicular (PP' in the diagram) as the 180°
and 0° (Greenwich) longitudes. The completed projec-
tion will appear as shown in Fig. 72.

The chief use of the Gnomonic Projection is to pro-
duce supplementary charts for the Mercator Projection
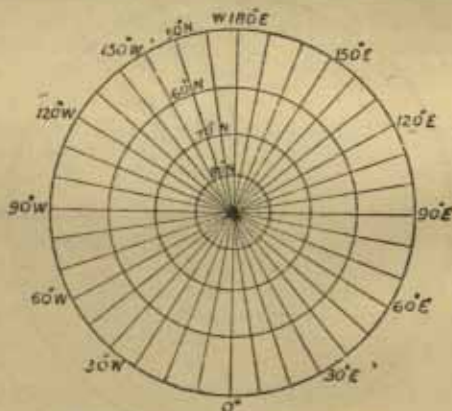sailing charts. To facilitate sailing by the great circle



Fig. 72 Scale : 1/160,000,000

routes, the Governments of the United States of America
and Great Britain have published Gnomonic Charts cover-
ing in single sheets the North Atlantic, the South Atlan-

tic, the Pacific, the North Pacific, the South Pacific, and the Indian Ocean.

The projection is also being used for the plans of harbours and polar charts.

The charts of the sky showing stars are also prepared on this projection.

Owing to the great exaggeration this projection is seldom used for Atlas maps.

### CONICAL PROJECTIONS

The conical projections include some of the most commonly used projections. The popularity of this group of projections among cartographers is shown by the fact that the atlas maps are drawn mostly on one or the other projection of this group. This popularity is due not only to the simplicity of construction and relative accuracy of the conical projections, but also because a map drawn, on such projections can be divided into sections which can be printed on different pages of the atlas. The importance of the conical projections is illustrated also by the fact that a projection of this group has been chosen for the International Map (Scale 1/M) of the world. It must be remembered that the greatest difficulty of selecting a suitable projection is in the mapping of the middle latitudes. It is for these latitudes that the conical projections, as a group, are the best.

It is important to note here that most of the conical projections are determined analytically and therefore are not 'projections' in the strict sense of the word. The elements of such projections are given by mathematical formula rather than by 'projection' or the shadow picture of the globe.

The most important projections of this class are :—

    (i) Simple Conical projection ;

    (ii) Simple Conical projection with two standard Parallels ;

9

(iii)  Bonne Projection ;

(iv)  Polyconic Projection ;

(v)  Sanson-Flamsteed or Sinusoidal Projection ;

(vi)  Lambert Conformal Conical Projection ;

(vii)  Albers Projection.

### SIMPLE CONICAL PROJECTION
#### (*With one standard parallel*)

In the simple conical projection the cone is supposed to be vertically above the pole. The standard parallel marks the part of the globe along which the cone touches it. This projection is never used in its true geometrical form, owing to the uneven spacing of the parallels in the original form. In practice, the spacing of the parallels is modified mathematically so that they are drawn evenly at their true distances.

The properies of the simple conical projection are that :—

(i)  the meridians are straight lines radiating from a point ;

(ii)  the parallels are concentric curves drawn at true intervals determined mathematically ;

(iii)  the scale is true only along the standard parallel. The scale is greatly exaggerated, however, as one moves away from this standard parallel. This is specially true east and west of the central meridian. North and south of the standard parallel the scale is rendered true because of modification by mathematical formula.

(iv)  the area is shown correctly only in a narrow strip along the standard parallel. This projection is not therefore an equal area projection.

(v)  Owing to the change of scale, the projection is also not a conformal projection.

The construction of this projection is simple. The graphical method described here gives an approximately

accurate projection. The circle drawn here gives the measurements for spacing the maridians and the parallels.

To construct the projection, describe a circle on the required scale (say 1/160 million which gives a radius of 1·56 inch). Select the standard parallel, say 30° N.

In the following diagram, the circle EPQ represents the globe, P the pole, and EOQ the equator. At the centre O make an angle of 30° by the radius OD. D marks the point where the standard parallel crosses the circle. At the point D draw a tangent P' D meeting the polar axis



(A)
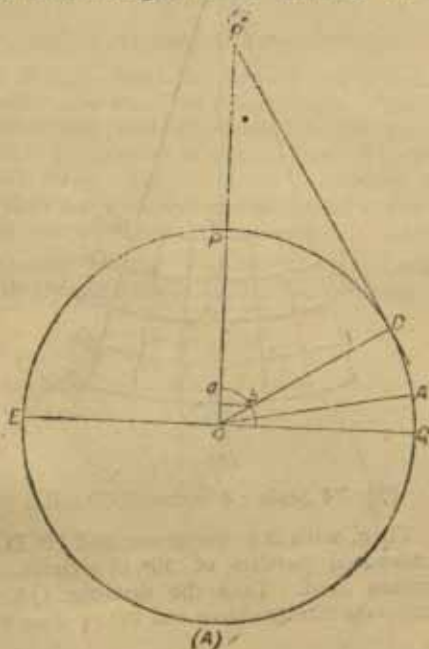
Fig. 73

produced at P. Mark off on the circle as shown, the radius OA fixing the interval at which the parallels are to be

shown on the projection. With QA` as radius and O as
centre describe a semi-circle cutting OD in b. From b draw
a line parallel to the equator to meet the polar axis in a.
Then ab is the measurement for dividing the standard
parallel for drawing the longitudes on the projection.
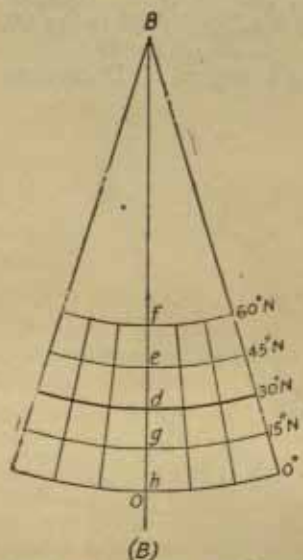Now, draw BO (as in Fig. 74 B) to represent the central



(B)

Fig. 74 Scale : 1 inch = 5000 miles

meridian. Then, with B as the centre and P' D as radius
draw the standard parallel of 30° as a curve, cutting the
central meridian in d. Take the distance QA and mark
with it equidistant points above and below d on the central
meridian.

With B as the centre, as before, and radii Be, Bf, Bg
and Bh draw the other parallels on both sides of the stan-
dard parallel.

Now, take the distance ab from the circle and divide the standard parallel. Through these points of division, draw meridians as straight lines converging on B. This completes the projection as shown in the diagram (74B) above.

The chief use of this projection is for making maps of relatively small areas with little latitudinal extent; like Denmark, Poland and Eire (Ireland).

### SIMPLE CONICAL PROJECTIONS

#### (*With two standard parallels*)

This is a further improvement on the simple conical projection with one standard parallel only. The improvement lies in selecting two standard parallels for division true to scale. It enables a wider extent of latitude to be shown in this way, and removes therefore the main handicap of the simple conical projection with one standard parallel, which suits only the narrow extent of latitude.

The properties of this projection are practically the same as of the simple conical projection with one standard
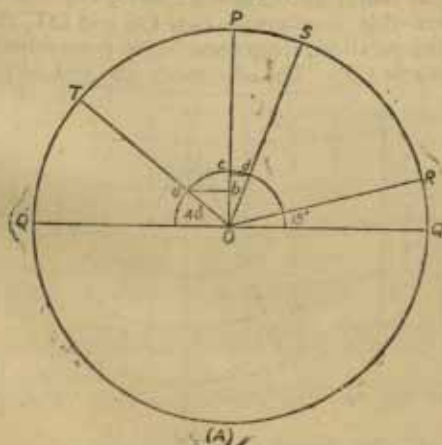


Fig. 75.

parallel. But owing to the selection of two standard parallels, there is a greater amount of accuracy in this projection. This projection is sometimes called the 'Secant Conic Projection', because to get two standard parallels the cone of projection has to be supposed to cut into the globe rather than cover it. There is, however, a separate secant conic projection which is entirely different from this projection.

The main problem involved in the construction of this projection is to find the radii of the two standard parallels. The rest of the construction is similar to that of the simple conical projection.

Describe a circle to represent the globe on the required scale as shown in the following diagrams. Draw the equator QQ' and the axis OP. Select the standard parallels, 40° and 70°. Draw radii OT and OS to mark on the circle the positions of the standard parallels, 40° and 70°, respectively. Draw also OR to mark the angle of the intervals at which the parallels are to be shown.

With QR as radius and O as the centre, describe a semicircle. Where this semi-circle cuts OS and OT, the radii of the standard parallels, from there drop perpendiculars ab and cd to the axis OP. The distances ab and cd give the
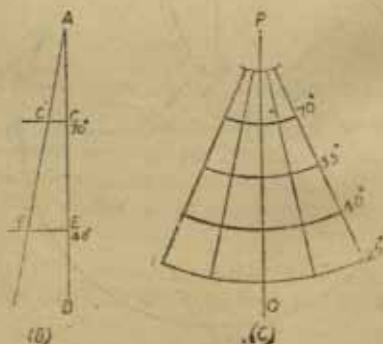


Fig. 76 Scale : 1 inch=4000 miles

spacings of the meridians at the standard parallels of 40°
and 70° respectively.

Now, to find the radii of the standard parallels, 40° and
70° make use of these spacings. Draw a straight line AB.
Divide it into sections equal to QR, as in Fig. 76-B. From
C and E on this line erect perpendiculars CC' and EE'
equal to cd and ab, spacings respectively for 70° and 40°
obtained from the circle in Fig. 74 on a previous page.
Through the points E' and C' draw a straight line extend-
ing it to meet AB in A. Then, A is the centre and AC
and AE give the radii of the standard parallels 70° and 40°
respectively.

The difference between the standard parallels is 30°,
which is represented here by the distance CE on the straight
line AB. We have decided to show the parallels at the
interval of 15°. The distance CE will therefore be divided
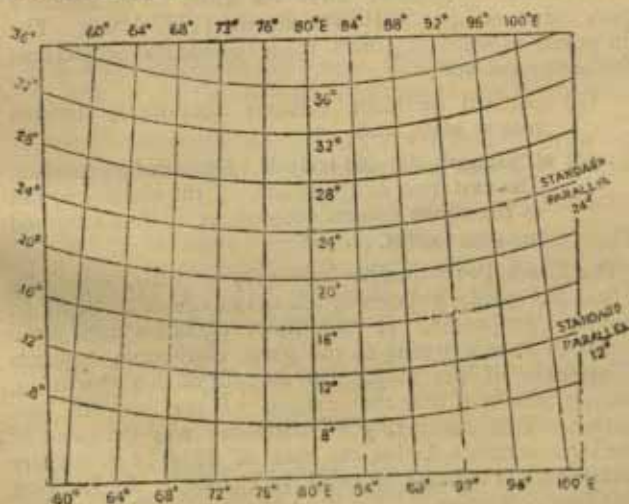into two equal parts. An equal distance will be marked



Fig. 77 Scale : 1 inch = 255 miles

above C and below E. Thus, AB, AD, and AF give the radii of the other parallels to be shown on the projection.

We can now draw the projection, as shown in the diagram 76-C above with P' as the centre for drawing the parallels. Draw the meridians as straight lines through the points of division on the standard parallels.

The standard parallels should be so selected as to cover two-thirds of the height of the map. This gives the best results.

This projection is neither an equal-area projection nor entirely orthomorphic. It is, however, good for drawing the atlas maps of Europe, Russia, and Scandinavia, etc. Asia is too big for it.

Fig. 77 gives this projection for India.

## BONNE PROJECTION*

The Bonne Projection owes its name to its author a French cartographer, Rigobert Bonne (1727-1795). The main point in which it differs from the conical projections described above are :—

> (a) standard meridian (central meridian), divided true to scale, and

> (b) all parallels divided truly like the standard parallel. The east-west exaggeration of the scale common to the above conical projections is thus removed to some extent.

The Bonne Projection has been very popular, especially in France, chiefly because of the advantage of its being an equal-area projection. It has, however, fallen from grace recently in France, owing to the great distortion, towards the margins of the map. On account of this distortion, distances measured near the margins of the map are not accurate. This inaccuracy of distances was the cause of great inconvenience during the war of 1914-18 in military operations. It is being replaced in France by the Lambert equal-area projection.

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* Pronounced 'BONE' not Boni.

The properties of this projection are :

(i) It has a fixed central meridian and a selected standard parallel, both divided true to scale.

(ii) The parallels are concentric curves at true distances and divided for meridians true to scale.

(iii) Except the central meridian, which is straight all the meridians are curves ; the curvature increasing towards the margins of the map.

(iv) Every small quadrangle in this projection has both its base and height true to scale. The projection is therefore equal-area projection.

(v) As the parallels and the meridians in this projection do not cut at right angles it is not a conformal projection. Shapes are accurate only along the central meridian.

The construction of the Bonne Projection is very similar to that of the two conical Projections described above.

Describe a circle on the scale selected. Draw the equator, QQ' as in Fig. 78 and draw the axis OP' producing it to P'.

Select the standard parallel, say 45°N. Draw the radius OC to mark its position on the circle at C. From C draw the tangent to meet OP produced in P'. Then P'C gives the radius of the standard parallel of 45°N.

Mark on the circle the positions of the other parallels by the radii OA, OB, OD and OE. From A, B, C, D and E draw lines parallel to the equator to meet the axis OP.

Mark the lengths of these parallels along the equator respectively as Oa, Ob, Oc, Od and Oe. Then the sections ab, bc, cd, de and eo give the divisions for the 75°, 60°, 45°, 30° and 15° parallels respectively.
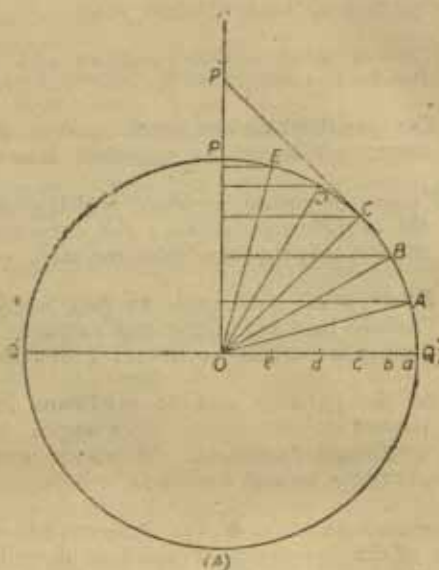
(A)

Fig. 78

With the measurements thus obtained, draw the projec-
tion as shown in Fig. 79. Draw a straight line to represent
the central meridian. With P' on this line as the centre and
P'C, the tangent on the circle, as the radius draw the stand-
ard parallel of 45°. Now, divide the central meridian,
both above and below the standard para lel, into parts
equal to the distance QA on the circle. With P' as the
centre draw parallels through these points of division.
Then, divide each parallel according to the distances obtain-
ed along the equator; i.e., ab, bc, etc. in Fig. 78 above.
Through these points of divisions on the parallels draw
curves to represent meridians.

It will be noted that the curvature of the parallels on
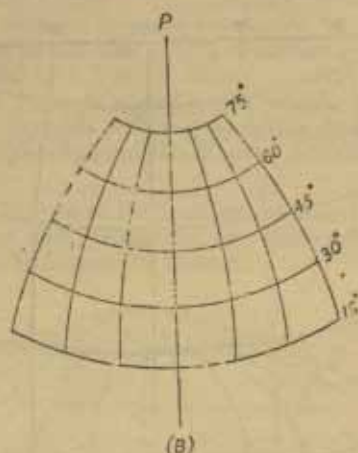this projection will be determined largely by the standard

(B)

Fig. 79 [Scale : 1 inch = 3450 miles]

parallel selected. The curvature is greater if a higher latitude is selected as standard parallel than if a lower latitude is so selected.

The Bonne Projection is good for any extent of *longitude* and suits most therefore the maps of Trans-Continental Railways, like the Trans-Siberan Railway.

It is used mostly for atlas maps of countries, especially for those which are sufficiently compact to avoid distortion at corners. Maps of Europe, Asia, and Australia etc., are made on this projection for atlases. But on account of its great extent Asia is not well shown on this projection.

The Bonne projection has also been used for survey maps of small areas in Scotland and Ireland, Belgium, Holland and Switzerland also use the this projection for survey maps.

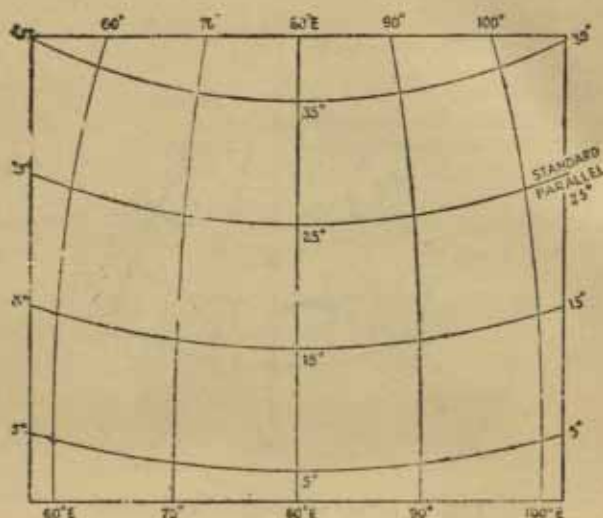The following gives a Bonne Projection for India :—



Fig. 80 [Scale : 1 inch = 1060 miles]

## SANSON-FLAMSTEED OR SINUSOIDAL PRO-JECTION

The projection makes use of sine curves which are like the rising and falling curves of waves. Its names ‘Sinusoidal’ is derived from this fact. The projection is, however, popularly known as Sanson-Flamsteed Projection after the name of its author, Sanson, a French Cartographer, and Flamsteed, the British Astronomer Royal, who used this projection very often for his star maps.

This *projection is a Bonne Projection with the equator as the standard parallel.* It was noted in the case of the Bonne projection that the curvature of the parallels was determined by the standard parallel. In this projection the standard

parallel, the equator, being a straight line all other parallels are therefore straight lines. The meridians, however, as in the case of the Bonne Projection are curves. It is, therefore not correct to say that it is a 'modified form' of the Bonne Projection. All the meridians in this projection converge at the poles in a map of the world. The intersections of the parallels with the meridians depart increasingly from the right angles as the distance from the central meridian increases.

With the difference of the parallels, as noted above, all the properties of this projection are those mentioned in connection with the Bonne Projection.
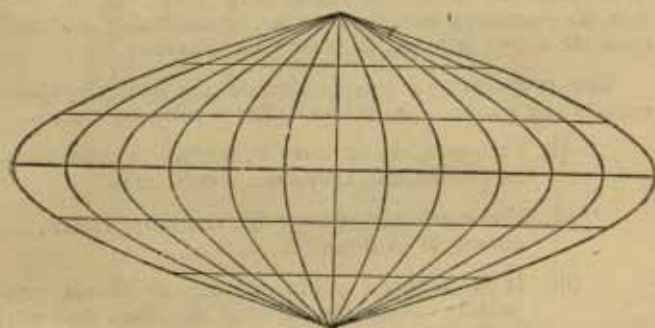


Fig. 81 [Scale : 1/450,000,000]

The construction is also similar. The only point of importance is that the central meridian here is half the length of the equator. The central meridian and the equator are divided true to scale by the length of the arc for the interval in degrees at which the parallels are to be drawn. The parallels are divided true to scale according to the method shown in the case of Bonne Projection.

The Sanson-Flamsteed Projection is best suited for areas near the equator, provided they do not have a very great north-south or east-west extent. Thus, Africa and South America can best be shown on this projection. It is not

suited for maps of Asia or Australia, because of their great
distance from the equator and a wide east-west stretch.

## POLYCONIC PROJECTION

The Polyconic Projection was devised by an American,
Ferdinand Hassler, the first superintendent of the U. S.
coast and Geodetic Survey. It is a link between the 'scien-
tific' and the 'conventional' projections. Its principle is
based on the assemblage, one over the other, of a number
of hollow cones. These cones give the parallels, which
have a separate tangent meeting the polar axis. Each paral-
lel has therefore a separate centre of its own. The projec-
tion as practically used is, however, considerably modified
from the above principle by mathematical tables.

The properties of this projection are generally those
expected in a conical projection. These properties are :—

(i) The parallels are curves ; but unlike other coni-
cal projections, they are not concentric.

(ii) The meridians, except the central meridian, are
curves, as in Bonne Projection.

(iii) It is neither a conformal nor equal-area pro-
jection. Near the central meridian, however,
it has the characteristic of both. Within a
distance of 560 miles from the central meridian,
the error in scale at any point on the map is
only about 1°.

(iv) The distortion in scale increases rapidly at the
margins of the map.

The construction of this projection is similar partly
to the Simple Conical projection and partly to the Bonne
Projection.

Describe a circle (Fig. 81) on the selected scale. Pro-
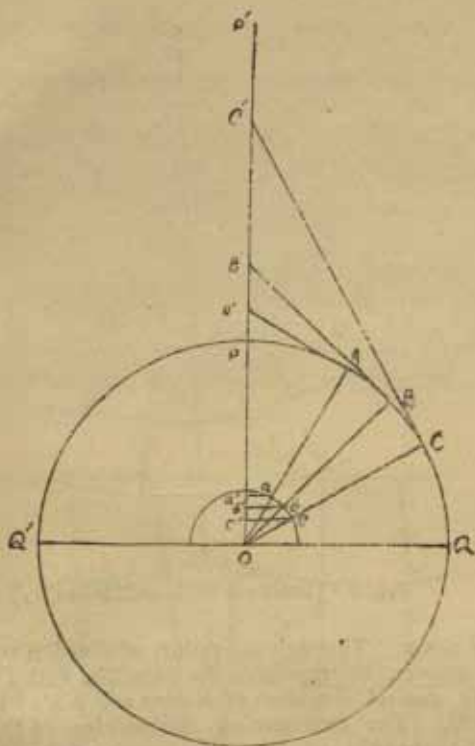ceed as in the case of the conical projections, described

Fig. 82

above, to get the measurements for dividing the central meridian and the parallels. Draw tangents from the points representing the various parallels on the circle to meet the polar axis produced to get the radii of the parallels.

Then draw the projection, as shown in Fig. 83 by having the central meridian OP' and dividing it by the distance CQ
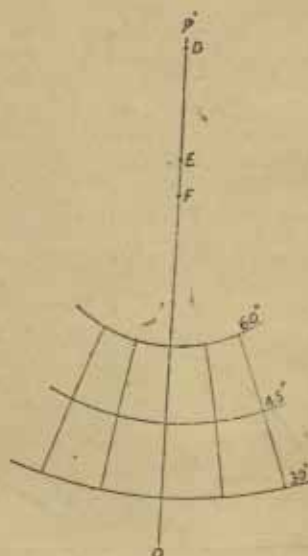
Fig. 83 [Scale : 1 inch = 2500 miles]

on the circle. Through the points of division so obtained draw curves, to represent the parallels, with D, E, and F on the central meridian as centres and AA', BB', and CC' as radii. For determining the position of D, E, and F, it is convenient to take the length of the radius of the parallel on the compasses. Place one leg of the compasses on the point of division on the central meridian representing the intersection of the parallel and then note how far the other leg goes towards P. Fix the metal leg there and draw the curve through the division point with the pencil leg.

Then divide the curves representing the parallels of 60°, 45° and 30 on the projection by aa', bb', and cc' respectively. Join the points of division by curves to show the meridians.

The chief use of this projection is to make maps of small areas necessitated by topographical surveys. The greatest advantage of this projection for this purpose lies in the fact that separate sheets may be plotted independently, with the help of tables. A large number of these sheets can be joined together afterwards, thus, giving a map of a large area without much error. For each sheet thus plotted the scale error is only about 1/1300. The ease of construction is another advantage of this projection.

There is, however, a limit to the number of sheets that can be joined together. It is to be noted that only those sheets can be joined together which have the same central meridian. In other words, the east-west joining of the sheets is not perfect. Ordinarily, more than nine neighbouring sheets cannot be joined together satisfactorily. This is shown below :—
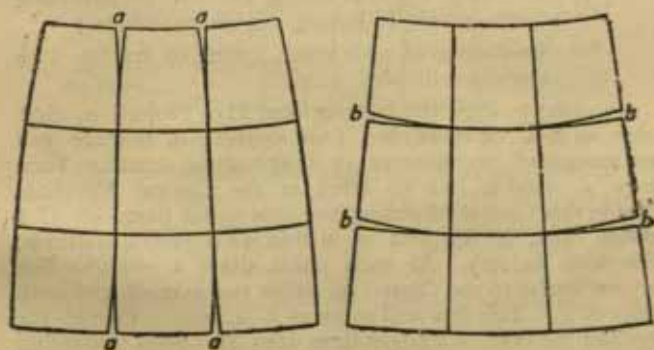


Fig. 83

The projection is not suited for large areas if the longitudinal extent is great. In fact this projection is good only for *wide latitudinal* and *narrow longitudinal* extent.

The importance of the Polyconic Projection is enhanced by the fact that a modified form of it has been selected for

drawing the International Map of the World. The modification has been devised by Lallemand.

In this modification the top and bottom parallels of each sheet are drawn from tables, but they are *not concentric*. These two parallels are then divided true to scale, as in the Polyconic Projection. The points of division are connected by *straight lines* which represent the meridians. Another modification is that the central meridian is not divided true to scale, but it is the two meridians 2° to the east and 2° to the west of tne central meridian of each sheet that are divided truly. The scale along the central meridian is therefore slightly reduced. But by dividing two meridians true to scale on each sheet the modification distributes the scale error.

The chief advantages of the modified form of the Polyconic Projection therefore are :—

(*a*) the fitting together of a number of adjoining sheets, owing to having straight meridians ;

(*b*) distribution of scale error, owing to having two meridians divided truly.

In order to draw the International Map Projection, first select an area not more than four degrees in latitude and not more than six degrees in longitudinal extent. Then draw a suitable line to serve as the Central Meridian. Divide this Central Meridian into four equal parts of 17·4 inches each, if the area is within 48 degrees of latitude, (See table below). At each point draw a straight line perpendicular to the Central Meridian and extending to both sides of it. This line will serve as a latitude. Divide the top and the bottom straight lines into six parts according to calculations given in Table B below. Join the corresponding points of division of the top and the bottom parallels by straight lines. Then, mark off above the proper points the distance (Table C below) by which the various perallels curve. Now draw smooth curves through all such points as well as the points where there is no curvature. The projection is now complete.

It will be seen from Table C below that there is no

curvature for the first longitude on both sides of the Central Meridian and for areas extending to 16° N. and 16° S. of the Equator.

The construction is shown in figures given below, the scale being reduced to suit the size of the page :—
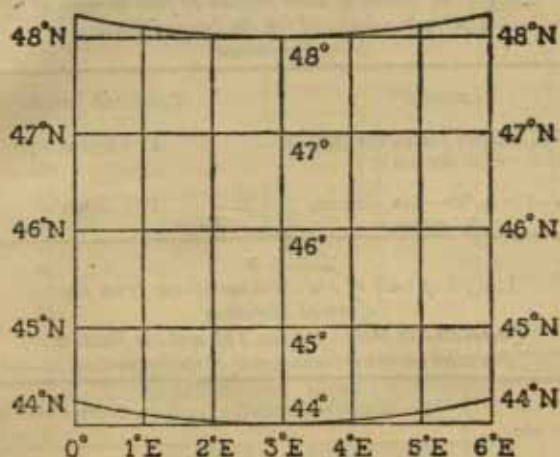


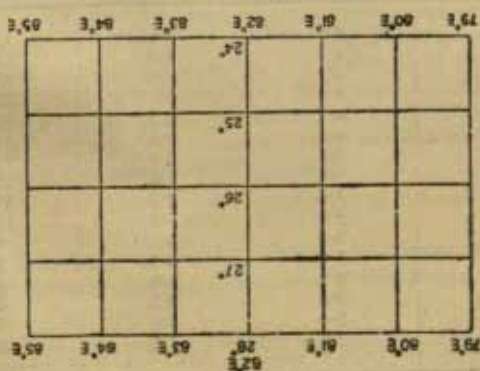Fig. 85. International Map Projection for Britain.



Fig. 86. International Map Projection for the Punjab.

It is convenient to make a plane scale of miles on the scale selected for the map projection first of all. This scale of miles helps in taking off the measurements. The method of making such a scale has been described on page 57.

TABLE A

*Length in inches of each section of four degrees of Latitude calculated for the International Map Projection*

| Latitude | Corrected length |
|---|---|
| 0—4⁰ degrees to 44⁰ to 48⁰ degrees each section | 17·4 inches |
| 48⁰—52⁰ to 56⁰—60⁰ degrees each section | 17·5 inches |

TABLE B

*Length of each of the three meridians from the Central Meridian*
*Calculated in inches for the Top and the Bottom Parallel on the International Map Projection.*

| Latitude (In degrees) | Longitude length in inches from Central Meridian | | |
|---|---|---|---|
| | 1 degree | 2 degrees | 3 degrees |
| 0 | 4·3 | 8·6 | 13·0 |
| 4 | 4·3 | 8·6 | 13·0 |
| 8 | 4·2 | 8·5 | 13·8 |
| 12 | 4·2 | 8·5 | 12·7 |
| 16 | 4·1 | 8·3 | 12·5 |
| 20 | 4·0 | 8·1 | 12·2 |
| 24 | 3·9 | 7·0 | 11·0 |
| 28 | 3·8 | 7·6 | 11·5 |
| 32 | 3·6 | 7·3 | 11·0 |
| 36 | 3·5 | 7·0 | 10·5 |
| 40 | 3·3 | 6·6 | 9·9 |
| 44 | 3·1 | 6·2 | 9·3 |
| 48 | 2·9 | 5·8 | 8·7 |
| 52 | 2·6 | 5·3 | 8·0 |
| 56 | 2·4 | 4·8 | 7·2 |
| 60 | 2·1 | 4·3 | 6·5 |

## TABLE C

*Curvature of Latitudes at Longitudes on both sides of the Central Meridian Calculated in* **Millimeters**

| Latitude (In degrees) | 1 degree | 2 degrees | 3 degrees |
|---|---|---|---|
| 8  |     | ... | 1 |
| 12 |     | ... | 1 |
| 16 |     | 1   | 2 |
| 20 |     | 1   | 3 |
| 24 |     | ·1  | 3 |
| 28 |     | 1·5 | 3·5 |
| 32 |     | 1·5 | 4 |
| 36 |     | 2   | 4 |
| 40 |     | 2   | 4 |
| 44 |     | 2   | 4 |
| 48 |     | 2   | 4 |
| 52 |     | 2   | 4 |
| 56 |     | 2   | 4 |
| 60 |     | 1·5 | 3·8 |

Table A, B and C have been adopted from Elements of map Projection by Deetz and Adams.

### CYLINDRICAL PROJECTIONS

The cylindrical projections are similar to the conical projections in that the basis of projection is the same ; the globe being projected on a developable surface. As in the case of the conical projections, the cylindrical projections are also considerably modified by mathematical tables before being used. There are a number of projections in this class, but with one exception, they are seldom used. This exception is the Mercator's Projection.

### MERCATOR PROJECTION*

The Mercator Projection derives its name from the assumed name of Gerhard Kraemer, a Flemish cartographer.

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* This is also known as cylindrical **Orthomorphic Projection**.

The projection, as in use today, is however, the result of the modification by Edward Wright of the University of Cambridge. This projection is of great practical value in navigation, because the bearing or direction to be followed by the ships between any two points can be shown on this projection simply by drawing a straight line connecting those points. This line of bearing, or the Rhumb line* or loxodrome can be easily followed by the ship with the help of the compass. It is this property of the Mercator projection which is responsible for its great popularity.

The properties of this projection are :—

    (i) The meridians and the parallels are shown by parallel straight lines, cutting each other at right angles.

    (ii) The equator is shown as a straight line drawn true to scale.

    (iii) The meridians are spaced *equally*.

    (iv) The parallels are spaced *unequally*, with a view to balance the distortion brought about by having straight meridians instead of curves as on a globe.

    (v) All bearings or loxodromes on this projection are shown by straight lines. This is due to the combination of the following two features :—

      (a) Balancing of scale both along the meridians and the parallels, and

      (b) The meridians and the parallels cut at right angles.

    (vi) The projection is conformal, and therefore the shapes on the map are correct. In higher latitudes, however, where the exaggeration in scale is considerable, the shapes are greatly

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* Rhumb is an old word meaning Compass direction.

*magnified* though not distorted. It must be noted that conformality in this projection applies only to points and not to large areas, for the scale changes constantly.

(vii) Areas are not correctly shown on this projection owing to the constantly changing scale. Along the equator, which is truly represented, however, both areas and shapes are correct.

(viii) The polar areas are greatly distorted, as the pole is shown by a straight line equal to the equator and not by a point as on the globe. Owing to the marked exaggeration of scale near the poles, this projection seldom extends beyond 85°, North or South of the equator. An idea of the exaggeration of the scale in the higher latitudes can be had by the fact that the areas are magnified about fifteen times on the 75th and about thirty-three times on the 80th parallel. It is on account of this exaggeration that on this projection Greenland appears to be greater than South America, though actually it is only about one-ninth.

(ix) The cardinal points, (north, south, east and west), always point the same way and remain parallel to the borders of the map. This property is of great import for meteorological charts.

*"Regardles of the frequent criticism of the use of a Mercator for a map of the world, the defects are after all, greatest in the polar regions. Generally our interests are centred between 65°N. and 55° south latitude, and it is in this belt that other projections present even greater difficulties when the world is mapped in one continuous sheet. When continuity and orientation as to cardinal directions

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* Deetz : Cartography.

are desired in this wide expanse of the earth's surface, the Mercator projection provides these special properties and avoids the discontinuities or breach of orderly arrangement seen in the other world maps. In respect to finding an equal area projection adapted to a strictly continuous map of the world, no satisfactory solution has yet been offered."

As has been mentioned above, the greatest merit of Mercator Projection is that straight lines on it are lines of *constant direction* (Rhumb lines). On no other map projection are the straight lines the rhumb lines. This fact has greatly increased the popularity of Mercator Projection for air navigation. To appreciate this superiority of Mercator's over other projections it must be realised that the actual earth's surface is a *curved* surface on which the direction to any point changes constantly. This constantly changing direction between two points is shown by a rhumb line, which is a curved line, and appears as curved line on map projections other than the Mercator's. On the surface of the earth if we take a sight on some distant object, say a wireless tower, the sight-line followed on the earth's surface will not have a constant direction, unless it is along a meridian or along the equator. For it will not intersect each successive meridian at the same angle The sight-line represents only an azimuth—the initial angle at the point of origin. If one follows the sight-line to reach the sighted object, one would have to change directions constantly. This would make it impossible to reach the destination. The sight-line and the path to be followed to reach the destination are two different things. The solution is given by the Mercator Projection by using only a *straightedge* line from the point of sight to the destination. The straightedge line has only one direction and indicates all the points through which the path to the destination will pass. This advantage of Mercator's arises out of the simple geometrical principle, that a transversal line cutting parallel lines makes all corresponding angles equal.

The distance given by the rhumb line navigation between two points is not the shortest, so that the straight line route given by Mercator is slightly longer than the

shortest route as given by the Great Circle route. But the difference is not great. The Great Circle route distance between New York and San Francisco and the rhumb line route distance, used by the air lines, between them is only about 30 miles shorter. The Mercator route is therefore generally followed.

This projection is constructed with the help of a table and is therefore simple. Draw a straight line EQ (3 inches long) to represent the equator on the scale selected. Divide EQ into twelve equal parts to show the meridian interval of 30° (any other interval may be selected). Draw PP' at right angles to EQ to represent the central meridian. Divide the central meridian according to the table given (column 3). Through the points of division on the central meridian draw parallels equal to the equator. Then, through the division on the equator draw straight lines at right angles to it to represent the meridians. The network of the projection is thus complete.
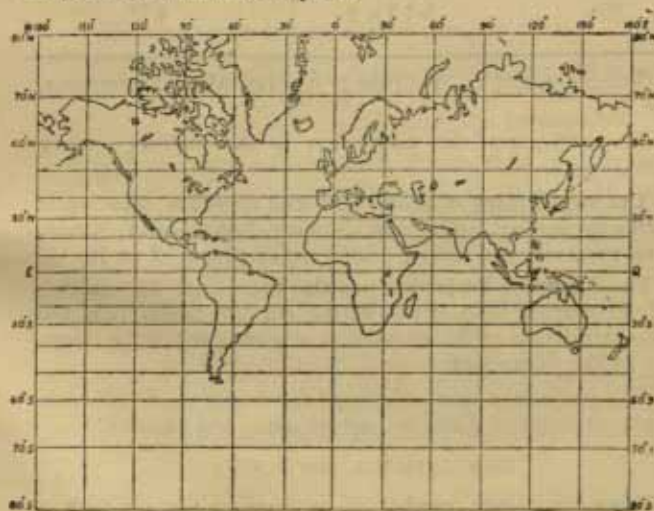


Fig. 87 [Equatorial Scale : 1/500,000,000]

The distances for 10° intervals can be calculated from the following table by multiplying the radius :—

TABLE D

| Degrees Latitude | Distances | Distances when R is 1·5" |
|---|---|---|
| 10° | ·17 × R | 25" |
| 20° | ·35 × R | ·5" |
| 30° | ·54 × R | ·8" |
| 40° | ·76 × R | 1·1" |
| 50° | 1·01 × R | 1·5" |
| 60° | 1·31 × R | 1·9" |
| 70° | 1·73 × R | 2·6" |
| 80° | 2·43 × R | 3·6" |
| 85° | 3·13 × R | 4·7" |

(From Garnett : A Little Book on Map Projections, page 65).

The chief use of this projection is for making sailing charts.

The world maps in atlases and wall maps are also made on this projection. The map showing directions of winds, ocean currents, and sailing routes are all prepared on it.

The Mercator Projection has also been used for making a Hydrographic Map of the World (in 24 sheets) on the recommendation of the committee responsible for the mapping of the ocean bed.

This projection cannot be used for comparison of areas or measurement of distances, except along the equator.

#### CONVENTIONAL PROJECTION

There are a large number of projections that produce a satisfactory network of meridians and parallels entirely by

analytical methods rather than by removing the defects of the socalled 'shadow projections'. The Mollweide and the Lambert projections are the most popular of such projections. The construction of these projections is done by the help of tables.

## MOLLWEIDE PROJECTION

This projection owes its name to its author, Karl B. Mollweide, a German cartographer. There are other names in use for this projection also; as the 'Homolographic projection' or the 'Elliptical projection'. The popularity of this projection is mainly due to its equal-area character. This projection can be easily recognised by its elliptical boundary.

The properties of this projection are :—

(i) All the parallels are straight lines and are *unequally spaced.*

(ii) All the meridians, except two, are ellipses.

(iii) The central meridian is a straight line and is only half the length of the equator. The meridian of 90° is a circle and bounds the hemisphere.

(iv) The equator is divided true to scale where alone on this projection the scale is true. The scale is exaggerated along the parallels and somewhat reduced along the meridians in the higher latitudes.

(v) The parallels are not true to scale. Those near the equator are a little smaller, while those near the poles are a little larger than they are on the globe. This, however, makes up the variation caused in the width between any two parallels. The projection therefore becomes an equal-area projection.

(vi) The distortion at the margins is considerable, but it is less than in the Sanson-Flamsteed Projection.

(vii) There is a great distortion in shape, especially in
      the equatorial and in the polar regions. This is
      the greatest defect of this projection.

The construction of the Mollweide Projection is rather
difficult, owing to drawing of ellipses. The method is
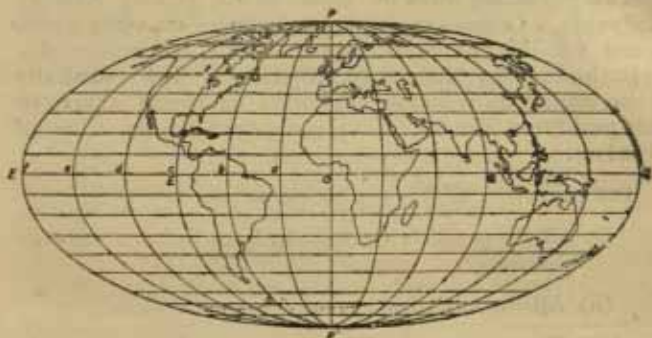shown in the following diagram :—



Fig. 88 [Scale : 1/450,000,000]

Draw a circle EPQP' with O as the centre, and 1·4 times
the length of the radius given by the scale. The circle so
drawn represents the 90th meridian and encloses the hemis-
phere. Draw the diameter EQ of this circle. Produce it
on both sides to Q' and E', taking care to make QQ' and
EE' equal to EQ. Then E' Q' is the equator. Also draw
the polar axis PP' to represent the central meridian.

Mark on this circle the points where the various latitudes
will intersect it, according to the angular measurements
given in the table below.

Through these points of intersection draw parallel to
the equator to represent the lines of latitude   Extend these
lines beyond the circle on both sides in such a way that the
length outside the circle will be equal to the length inside
the circle.

Through the outer ends of these lines representing latitudes draw the bounding ellipse. This ellipse is the 180° meridian.

Now divide the equator and all other parallels to it into the desired number of equal parts for drawing the meridians. Through the corresponding points of division draw elliptic curves to represent meridians.

This completes the projection.

The chief use of this projection is for drawing maps showing distributions which require equal-area projection for purposes of comparison.

This projection is not popular in the United States of America, as this country lies on the margins of the projection and is therefore greatly distorted in shape when the Greenwich meridian is taken as the central meridian. When any other meridian suitable for showing the United States of America is taken as the central meridian, Europe is greatly distorted.

The following table gives the angular measurements from the equator for finding out the points of intersection on the hemispherical circle :—

TABLE E

| Latitudes (In degrees) | Angular Distance (In degrees) |
|---|---|
| 10 | 8 |
| 20 | 15·8 |
| 30 | 23·8 |
| 40 | 32· |
| 50 | 40·5 |
| 60 | 49·5 |
| 70 | 59·5 |
| 80 | 71 |

Through the points thus obtained on the circumference, parallels to the equator are drawn. Points for drawing

these parallels may also be obtained by dividing the polar axis of the hemispherical circle according to the following table :—

TABLE F

| Latitudes (Degrees) | Distances from the equator |
|---|---|
| 10° | ·13 × Radius |
| 20° | ·27 × ,, |
| 30° | ·40 × ,, |
| 40° | ·53 × ,, |
| 50° | ·65 × ,, |
| 60° | ·76 × ,, |
| 70° | ·86 × ,, |
| 80° | ·94 × ,, |
| 90° | 1·00 × ,, |

## TRIGNOMETRICAL CONSTRUCTION

### (ONLY FOR THOSE INTERESTED)

The invention of map projections is primarily due to mathematics. The measurements of the co-ordinates are obtained correctly therefore only by mathematical calculations. The measurements obtained by graphic method are only approximate. However, the difference between the measurements obtained by these different methods is so small, especially in small scales, that for map-making any of the two methods may be used. The formula that are used in mathematics for constructing map projections have been derived mainly with the help of trignometry. The mathematician therefore tries to *prove*, by reference to trignometry, that these formulae are correct. He gives the whole process, step by step. The geographer's business is only to *use* these formulae in working out the various measurements that he will need for drawing the network of longitudes and latitudes. These mathematical formulae are most convenient for large scales in which the size of the circle representing the reduced earth is too large for using the graphic method.

Among the most important projections in use are the various kinds of conic projections. The mathematical formula for these projections is used to find :—

(i) the radius of the standard parallel,

(ii) the spacings along that parallel and along the central meridian.

The use of mathematical tables is necessary in finding these things.

### Simple Conic (with one Std. Par.)

The formula for this projection to find the radius of the Standard Parallel is :—

### R COT LAT.

The formula for finding the spacings along the Standard Parallel is :—

$$\frac{2 \pi R \cos \text{Lat.}}{360}$$

This gives the spacings for the projection where the projection interval is only 1°. It must be multiplied by the interval given, *e. g.*, if the interval be 10°, then the above formula will appear as

$$\frac{2 \pi R \cos \text{Lat.} \times 10}{360}$$

The spacings for the Central Meridian are obtained for 1° interval only (to be multiplied as above for higher intervals) by the following :—

$$\frac{2 \pi R}{360}$$

In the above formulae the R is the number of inches given by the scale for drawing the reduced earth. The cos and cot values are found from the mathematical tables (see appendix) given for each degree of latitude. The $\pi$ has a fixed value of 3·14. These values are multiplied to give the required results.

We have already mentioned above that the R is obtained by multiplying the R. F. by 250 millions.

With the measurements ready, the drawing of the projection is done in the same way as in the graphic method. Here also if the radius of the standard parallel is too large for the compass, the projection cannot be drawn.

We shall now work out an example.

On the scale of 1/150,000,000 construct a Simple Conic (with one std. par.) Projection for a sufficiently large area whose standard Parallel is 50°N and Central Meridian 80°E. The Projection Internal is to be of 15°.

The R on the above scale is $= \dfrac{1 \times 250,000,000}{150,000,000} = 1·6''$

The radius of the Standard Par. $= 1·6 \times ·83 = 1·3''$

The spacings on the Std. Par. $2 \times 3·114 \times 1·6 \times ·64 \times 15 \div 360 = ·26$

The spacings on the Central M. $2 \times 3·14 \times 1·6 \times 150 \div 360 = ·42$

Following the graphic method described on page 134 a projection can now be drawn with the above measurements. It will appear as in Fig. 89.
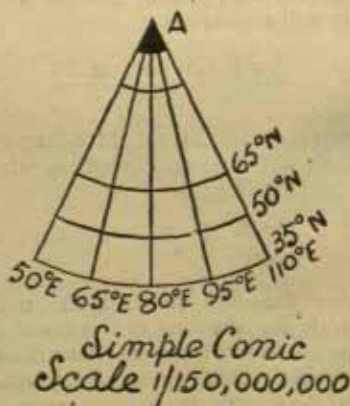


Simple Conic
Scale 1/150,000,000

Fig. 89

## CONIC (WITH TWO STD. PAR.)

It will be remembered that the Conic Projection with two Standard Parallels is a Secant Projection in which the cone is supposed to dig into the globe and thus touch it at two circles. This digging slightly complicates the calculation of the radii of the two parallels which are selected as the Standard Parallels. There is one formula for finding out the radius of the higher latitude. To this radius is added the difference between the radii of the two standard parallels. There is another formula to get this difference. The addition of the difference to the radius of the higher standard parallel gives the radius of the lower standard parallel.

With these two radii the curves for the two Standard Parallels are drawn from the same centre selected on the straight line drawn to represent the Central Meridian. The construction is the same as in graphic method.

The radius of the higher parallel, here known as $\varphi''$, is found by

$$2 \pi R \cdot \frac{\varphi'' - \varphi'}{360} \cdot \frac{\cos \varphi'}{\cos \varphi' - \cos \varphi''}$$

The difference between the two Standard Parallels is found by

$$2 \pi R \cdot \frac{\varphi'' - \varphi'}{360}$$

We shall draw a projection on the scale of 1/150 M. With 65°N. and 35° N as the Standard Parallels and 15° as the Projection Interval.

The R on the above scale is $\dfrac{1 \times 250,000,000}{150,000,000} = 1 \cdot 6''$

The radius of the Std. Par. 65° $(\varphi'') = 2 \times 3 \cdot 14 \times 1 \cdot 6 \times$

$$\frac{30}{360} \times \frac{\cdot 42}{(\cdot 81 - \cdot 42)} = \cdot 9''$$

The radius of the Standard Par. 35° $(\varphi^1) = \cdot 9 + (2 \times 3 \cdot 14$

$$\times 1 \cdot 6 \times \frac{30}{360})$$

$$= 1 \cdot 7''$$

Spacings for the Std. Par. 65° $= 2 \times 3 \cdot 14 \times 1 \cdot 6 \times \cdot 42 \times$

$$\frac{15}{360}$$

$$= \cdot 17''$$

Spacings for the Std. Par. 35° $= 2 \times 3 \cdot 14 \times 1 \cdot 6 \times \cdot 8 \times$

$$\frac{15}{360}$$

$$= \cdot 34''$$

Spacings along Central Meridian $= 2 \times 3 \cdot 14 \times 1 \cdot 6 \times \dfrac{15}{360}$

$$= \cdot 42''$$

The Projection will appear as in Fig. 90
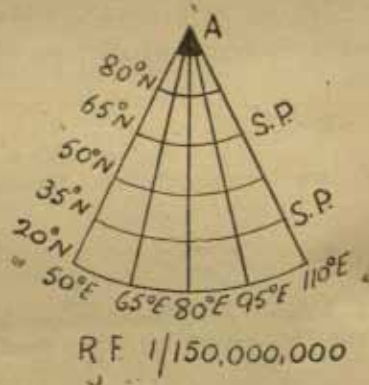


R F 1/150,000,000

Fig. 90

For Polyconic Projection and for Bonne Projection the calculations are obtained in the same way for the Standard Parallels and the Central Meridian as in the Simple Conic Projection (with one Std. Par.).

## HOW TO RECOGNISE PROJECTIONS

The Polar Zenithal is quite easy to recognise because of its unmistakable shape. The others can be recognised by the following hints :—

1. If the meridians are parallel straight lines the projection is *cylindrical*.

2. If the meridians are converging straight lines it is *conical*.

3. If the meridians are curved, the projection is *Bonne's*

if the parallels are concentric circular arcs ;
*Zenithal*, if the parallels are other curves.

*Sanson-Flamsteed's*, if the parallels are equidistant straight lines, and

*Mollweide's* if the parallels are equidistant straight lines approaching nearer to each other towards the Poles.

## CHOICE OF A PROJECTION

This can be determined by considering whether the map will represent

The World

Extensive Equatorial Areas

Regions North or South of Equator.

The World can be represented either in hemisphere or as a whole.

In reality, however, the choice of map projection depends chiefly on the shape and the size of the area to be represented. The special purpose for which the projection is required plays a less important part.

The diagram on next page compares how a certain part of the earth's surface will appear on the Globe and on the projections of the globe :—
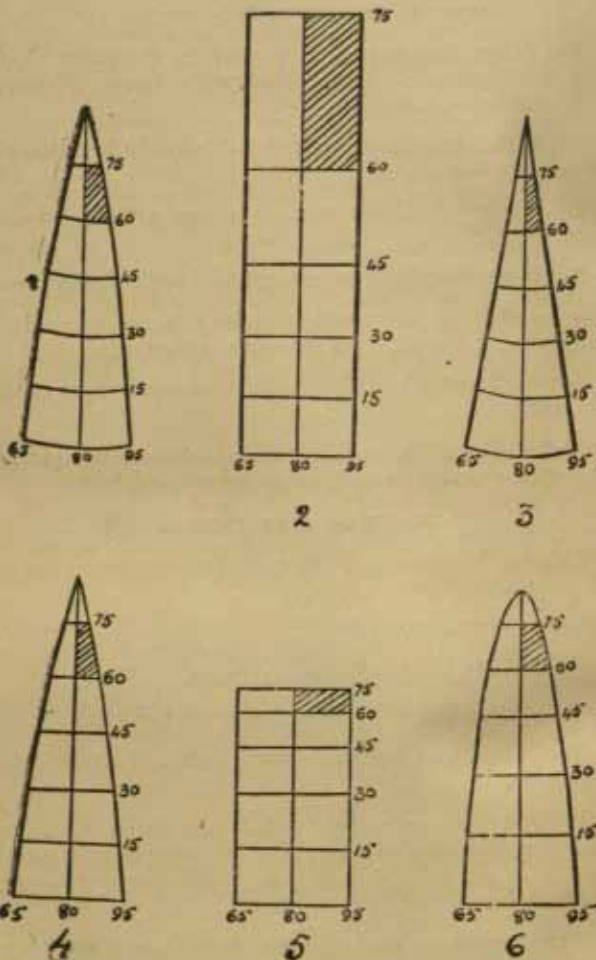
Fig. 91
1. Globe.   2. Mercator Projection.   3. Conical Projection.
4. Sanson Flamsteed Projection.   5. Cylindrical Projection.   6. Moll-
weide Projection.

### MAP GRID

Measurement of distances, directions, or fixing of positions on a map is always done with reference to the lines of latitudes and longitudes. These lines are referred to as co-ordinates. They are, however, not drawn in the same way on all maps. They differ according to the map projection used. In some maps they are straight lines, in others they are curves. In some maps they are parallel, in others they are not. Measurement of directions is therefore always difficult from these co-ordinates.

In order to facilitate the fixing of positions and the determination of direction of places, the military authorities have introduced a system of lines running north-south and east-west corresponding to the co-ordinates. They call these lines "northings" and "eastings" respectively. The system of these lines divides every map into squares which supersede the rectangles on the maps as drawn by the map projection used. This system of squares is known as the "Grid System."

The plotting or measurement of co-ordinates can be made from the nearest grid line. The grid squares are some multiples of ten units, though it is immaterial what the actual unit is. Also the grid squares are of a convenient size.

Sometimes, these grid squares are supplied printed separately on a tissue paper which can be used by placing on the maps on which only the co-ordinates are printed. In other cases, they are printed on the maps, eliminating the co-ordinates altogether.

Reference to places on the maps is always made by means of numbers, and not directions. For this purpose the squares are numbered by letters and the grid lines by numbers standing for tens of units of measurement adopted for the grid system for the map. Thus, if a place is situated in the square M, say 30 miles along the line running east-west and 11 miles along the line north-south, then it will be referred to as "M 3011." Here M will denote the square, 30 the distance along the easting, and 11 the distance along the northing. The position is thus accurately fixed.

SUMMARY OF PROJECTIONS

| Projection | Properties | Use |
|---|---|---|
| Gnomonic | (i) All great circles showing shortest distance are straight lines. (ii) Directions from centre are correct. (iii) Straight meridians and circular parallels. (iv) Exaggeration of scale towards margins, causing distortion there in shape, distances and areas. (v) Full hemisphere not practicable on it. (vi) Construction difficult, except for polar areas. | Supplementary sailing charts for Mercator. Plans of harbours. Not used for areas more than 30° distant from the centre. |
| Simple conical (one standard parallel) | (i) Straight meridians. (ii) Concentric curves for parallels. (iii) Scale true only along standard parallel. (iv) Neither equal-area nor conformal. | For small areas in middle latitudes, like Denmark, Poland and Ireland. |

| | | |
|---|---|---|
| Simple conical (two standard parallels) | Same as above. | For large areas with greater latitudinal extent. |
| Bonne | (i) Fixed straight central meridian. (ii) Parallels equidistant concentric curves. (iii) Curved meridians. (iv) Equal-area but not conformal. (v) Exaggeration on margins. | Survey maps in Holland and Belgium, etc. Good for any extent of longitude and therefore for transcontinental railways. |
| Sanson Flamsteed | Same as Bonne. | For large but compact areas Europe, Australia, etc. |
| Polyconic | (i) Parallels are non-concentric curves. (ii) Meridians curved, except the central. (iii) Small scale error near-central meridian. (iv) Neither conformal nor equal-area. (v) Its modification for 1/M map has straight meridians. | Best for areas near equator; Africa or South America. For survey maps when modified. The International Map on its modification. |

| Projection | Properties | Use |
|---|---|---|
| Mercator | ( ) Parallels and meridians straight; Parallels equal in length to equator. (*ii*) Meridians spaced equally, but parallels spaced unequally. (*iii*) All bearings shown by straight lines. This is the best advantage. (*iv*) Conformal projection for points (*v*) Areas greatly exaggerated. (*vi*) Pole shown by a straight line instead of a point. (*vii*) Cardinal points point the same way. | Sailing charts. World maps in atlases. Routes, direction of winds or ocean currents. Climatic maps generally. Also Hydrographic Map of World. |
| Mollweide | (*i*) Straight parallels, placed unequally. (*ii*) Elliptic meridians, except central and 90th. (*iii*) Equator divided truly, (*iv*) Distortion in shape. Equal area projection. | Distribution maps, especially World maps. Not popular in U. S. A. |

## EXERCISES

1. What are map-projections ? Why are they necessary ?

2. Write short notes on :—

    (a) Equal-area projections. (b) Orthomorphic projections, (c) Azimuthal projections.

3. Give the properties, construction, and uses of any of the following projections —

    (a) Gnomonic projection ;

    (b) Simple conical with two standard parallels :

    (c) Bonne projection ;

    (d) Polyconic projection ;

    (e) Sanson-Flamsteed projection ;

    (f) Mercator projection ;

    (g) Mollweide projection.

4. Give an account of the characteristics, uses and limitations of Mercator's Projection.

5. Construct a simple conical projection on the scale of 1/50,000,000, with the standard parallels of 40° N. and 70° N. and the central meridian of 30° W.

6. Construct a Bonne projection on the scale of 1/150,000,000, selecting 40° N. as the standard parallel and 80° E. as the central meridian.

7. Construct a Bonne projection for a map of India on the scale of 1 inch to 500 miles.

8. Construct a simple conical projection with two standard parallels for a map of Japan on the scale of 1 inch to 300 miles. (Parallels 30° to 45°N. only and Meridians 130° to 145°E. only.)

9. Construct an International Map Projection for a map of the Punjab and Rajputana (showing areas between 24° N. and 28° N. latitudes and 72° E. and 78° E. longitudes).

## TABLE G

*Length of 1 degree of Latitude (in Statute Miles)*

| | | | | | |
|---|---|---|---|---|---|
| From the Equator to | | 10° | | 68·69 miles | |
| ,, | 10° | to | 20° | 68·7 | ,, |
| ,, | 20° | to | 40° | 68·77 | ,, |
| ,, | 40° | to | 60° | 69·0 | ,, |
| ,, | 40° | to | 80° | 69·21 | ,, |
| ,, | 80° | to | Pole | 69·38 | ,, |

## TABLE II

*Length of 1 degree of Longitude at Latitude*

| Latitude | Statute Miles | Latitude | Statute Miles |
|---|---|---|---|
| 0 | 69.1 | 25 | 62.7 |
| 1 | 69.1 | 26 | 62.2 |
| 2 | 69.1 | 27 | 61.6 |
| 3 | 69.0 | 28 | 61.1 |
| 4 | 69.0 | 29 | 60.5 |
| 5 | 68.9 | 30 | 59.9 |
| 6 | 68.7 | 31 | 59.3 |
| 7 | 68.6 | 32 | 58.7 |
| 8 | 68.5 | 33 | 58.0 |
| 9 | 68.3 | 34 | 57.4 |
| 10 | 68.1 | 35 | 56.7 |
| 11 | 67.9 | 36 | 56.0 |
| 12 | 67.6 | 37 | 55.3 |
| 13 | 67.4 | 38 | 54.5 |
| 14 | 67.1 | 39 | 53 8 |
| 15 | 66.8 | 40 | 53.0 |
| 16 | 66.5 | 41 | 52.2 |
| 17 | 66.1 | 42 | 51.4 |
| 18 | 65.8 | 43 | 50.6 |
| 19 | 65 4 | 44 | 49.8 |
| 20 | 65.0 | 45 | 48.9 |
| 21 | 64.6 | 46 | 48.1 |
| 22 | 64.1 | 47 | 47.2 |
| 23 | 63.7 | 48 | 46.3 |
| 24 | 63·2 | 49 | 45.4 |

| Latitude | Statute Miles | Latitude | Statute Miles |
|----------|---------------|----------|---------------|
| 50 | 44.5 | 63 | 31.4 |
| 51 | 43.6 | 64 | 30.4 |
| 52 | 42.6 | 65 | 29.3 |
| 53 | 41.7 | 66 | 28.2 |
| 54 | 40.7 | 67 | 27.1 |
| 55 | 39.7 | 68 | 25.9 |
| 56 | 38.7 | 69 | 24.8 |
| 57 | 37.7 | 70 | 23 7 |
| 58 | 36.7 | 75 | 17.9 |
| 59 | 35.7 | 80 | 12.0 |
| 60 | 34.6 | 85 | 6.0 |
| 61 | 33 6 | 90 | 0.0 |
| 62 | 32.5 | | |

Note :—

The length of a degree of longitude can be found out for any degree of latitude by the following simple method : —

Draw a quadrant with the equatorial radius of 69 mm. (on the scale of 1 mm. for 1 mile) which equals the length of 1 degree of longitude at the equator. Make in this quadrant the angle representing the latitude. From the point where the arm of this angle touches the arc of the quadrant draw a perpendicular to the polar axis. This prependicular is parallel to the equator. Measure the length of this prependicular. That will give the length of 1 degree of longitude at that latitude. The scale of the quadrant may be varied according to convenience.

The following diagram illustrates this :—
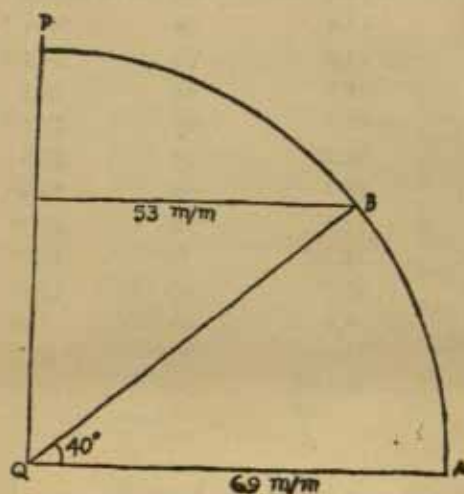


Fig. 92

TABLE I

The Statute Mile is a mile that is fixed by the Statute or law. In India and England the Statute Mile is fixed at 1760 yards or 5280 feet.

A Geographical Mile is 1 minute of a degree of latitude. This comes to about 6046 to 6108 feet. A Geographical Mile is usually taken as 1·25 Statute Mile.

A Nautical Mile is equal to 2026 Yards or 6080 feet.

## TABLE J

| Lat. | Cot. | Cos. | Lat. | Cot. | Cos. |
|------|------|------|------|------|------|
| 10 | 5·6 | ·98 | 31 | 1·6 | ·85 |
| 11 | 5·1 | ·98 | 32 | 1·6 | ·84 |
| 12 | 4·7 | ·97 | 33 | 1·5 | ·83 |
| 13 | 4·3 | ·97 | 33 | 1·4 | ·82 |
| 14 | 4 | ·97 | 35 | 1·4 | ·81 |
| 15 | 3·7 | ·96 | | | |
| | | | | | |
| 16 | 3 4 | ·96 | 36 | 1·3 | ·8 |
| 17 | 3·2 | ·95 | 37 | 1·3 | ·79 |
| 18 | 3 | ·96 | 38 | 1·2 | ·78 |
| 19 | 2·9 | ·94 | 39 | 1·2 | ·77 |
| 20 | 2·7 | ·93 | 40 | 1·1 | ·76 |
| | | | | | |
| 21 | 2·6 | ·93 | 41 | 1·1 | ·75 |
| 22 | 2·4 | ·92 | 42 | 1·1 | ·74 |
| 23 | 2·3 | ·92 | 43 | 1 | ·73 |
| 24 | 2·2 | ·91 | 44 | 1 | ·71 |
| 25 | 2·1 | ·90 | 45 | 1 | ·7 |
| | | | | | |
| 26 | 2 | ·89 | 46 | ·96 | ·69 |
| 27 | 1·9 | ·89 | 47 | ·93 | ·68 |
| 28 | 1·8 | ·88 | 48 | ·9 | ·66 |
| 29 | 1·8 | ·87 | 49 | ·86 | .65 |
| 30 | 1·7 | ·86 | 50 | ·83 | ·64 |

## TABLE

| Lat. | Cot. | Cos. | Lat. | Cot. | Cos. |
|------|------|------|------|------|------|
| 51 | ·8 | ·62 | 61 | ·55 | ·48 |
| 52 | ·78 | ·61 | 62 | ·53 | ·46 |
| 53 | ·75 | ·6 | 63 | ·5 | ·45 |
| 54 | ·72 | ·58 | 64 | ·48 | ·43 |
| 55 | ·7 | ·57 | 65 | ·46 | ·42 |
| 56 | ·67 | ·55 | 66 | ·44 | ·4 |
| 57 | ·64 | ·54 | 67 | ·42 | ·39 |
| 58 | .62 | ·52 | 68 | ·4 | ·37 |
| 59 | ·6 | ·51 | 69 | ·38 | ·35 |
| 60 | ·57 | ·5 | 70 | ·36 | ·34 |

# INDEX