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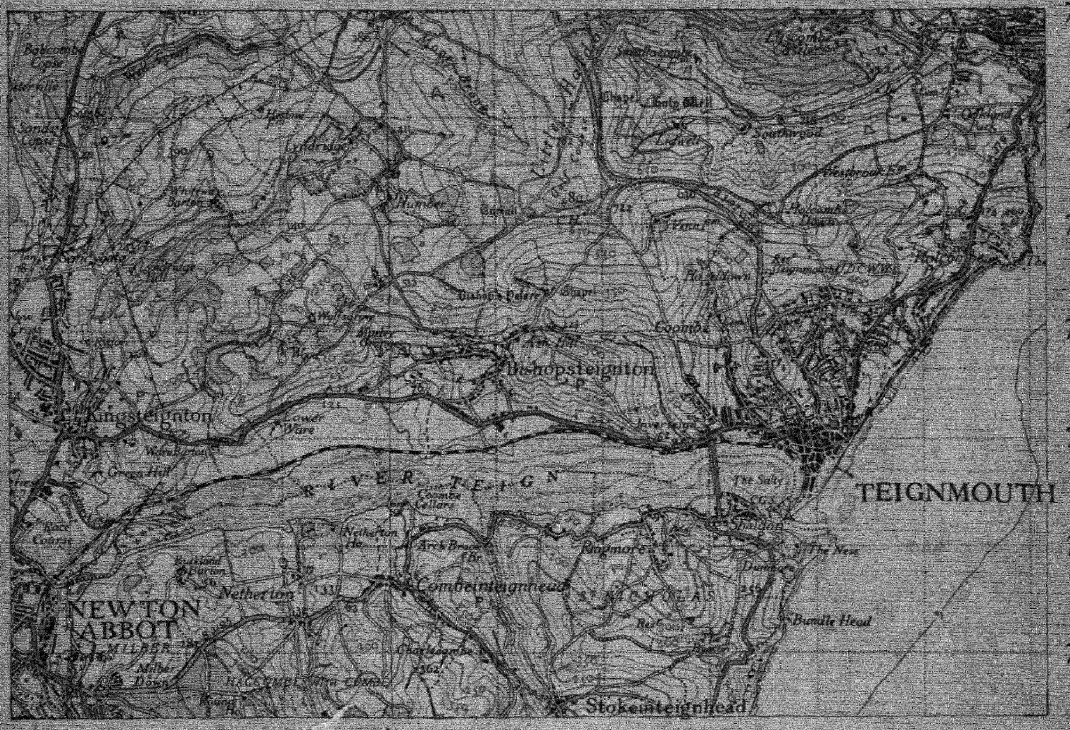
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AN INTRODUCTION TO
MAPWORK AND PRACTICAL GEOGRAPHY

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Ordnance Survey, 1951.

AN INTRODUCTION TO
MAPWORK AND PRACTICAL GEOGRAPHY

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PREFACE

THIS book has been designed to provide an introductory course in map reading and practical geography suitable for use in the upper forms of schools and in first year University classes. Care has therefore been taken to include all that is required in the subject for the various Higher School Certificate and University Intermediate examinations. The first ten chapters, especially those dealing with Ordnance and Weather Maps, contain much material suitable for School Certificate purposes.

The scope of the book will be apparent from the table of contents. The chapters have been so arranged that matter required in connection with the various examinations may be easily referred to. Thus Part I. directly covers the London University Intermediate Arts and Science syllabus in Mapwork. Part II. first gives some elementary aspects of surveying relative to map-making, and then in Chapter XVIII. deals with the interpretation of Geological maps as an aid to the study of topographical maps. Thus Part II. will serve as an introduction to the knowledge of surveying methods and uses of instruments required for most degree examinations in Geography.

A notable feature is the inclusion of portions of seven actual Ordnance Survey maps. These, together with the notes provided, should prove invaluable to the student. The weather map is also dealt with in great detail, and many typical examples are reproduced and discussed.

The problem of map making is approached in a clear manner, so that students will realise how survey work gives the data for the map, and why particular projections are selected for particular purposes. Simple graphical methods for constructing important projections are carefully explained.

Many useful questions and exercises have been included at the end of the book. These have been carefully selected and grouped into sections, at the head of which reference is made to chapters dealing with the subject of such sections. Many of the mapwork exercises are actual questions set at various Cambridge School Certificate and Higher School Certificate examinations, and for permission to include these thanks are due to the Local Examinations Syndicate of the University of Cambridge. They form [illegible] groundwork for map analysis

exercises set in London Intermediate and similar examinations. Many are based on Ordnance Maps, and are more concrete than "manufactured" examples. Numerous original questions are set on the Ordnance Maps included in this book, and most of them can be applied to other Ordnance Maps. Some tolerably advanced exercises are given in connection with Part II. They are mainly designed to emphasise the application of surveying methods to mapwork.

Thanks are also tendered to the Directors of the Ordnance Survey, the Geological Survey, and the Meteorological Office, as well as to the Controller of H.M. Stationery Office, for permission to reproduce certain maps and diagrams, etc., and to Messrs. J. H. Steward, Ltd., for the loan of blocks for Figs. 86, 87, 88, 96, 97, 106, 110, 114, and 115. Acknowledgement is made to Messrs. George Routledge, Ltd., for permission to use some diagrams from the writer's *Eastern England.* In the text specific reference is made to such diagrams and to those reproduced by permission of the various authorities noted above.

Professor A. G. Ogilvie of Edinburgh University, Professor Kenneth Mason of Oxford University, Mr. J. A. Steers, Dean of St. Catharine's College, Cambridge, have read proofs and made valuable suggestions concerning chapters devoted to subjects in which they are specially interested. Dr. R. E. Dickinson of University College, London, has helped with useful suggestions. To all these and to Mr. S. L. Boot, who kindly checked the mathematical calculations, the author expresses his deep gratitude.

J. B.

NOTE TO THE SECOND EDITION

For this revised edition certain diagrams have been redrawn or amended, a few new diagrams have been introduced, and new matter has been incorporated in Chapters I., II., IV., VII., XIII. Endeavour has also been made to simplify, and remove any ambiguity from, portions of the text, and the Ordnance maps have been inserted in slightly different and more convenient positions. The diagram numbers and page numbers remain, however, substantially the same as in the previous edition.

J. B.

NOTE TO THE THIRD EDITION

For this edition Chapter IX has been completely re-written in conformity with modern developments, and a specimen of the New Popular (Sixth) Edition of the One-Inch Ordnance Survey Map with the National Grid has been added in Chapter IV. An introduction to Regional Survey, designed to help candidates for University Diplomas and Degrees, from whom regional description of a selected area is required, has been included as an Appendix. A few minor alterations have been made elsewhere, where these have seemed desirable to keep the text up to date, but the diagram numbers and pagination of the previous editions have been retained as far as possible.

J. B.

NOTE TO THE FOURTH EDITION

In this edition all the One-Inch Ordnance Survey Maps are of the New Popular (Sixth) Edition, and a specimen of the $2\frac{1}{2}$-inch map has also been included. In Chapter XIII an explanation of the National Grid has been added and the diagram (Fig. 81) has been included by permission of the Controller, H.M. Stationery Office. In Chapter VIII, two statistical diagrams (Figs. 35, 37) have been redrawn to give greater clarity. In the exercises on Weather Maps (page 228 *et seq.*) some additional questions have been given from papers set for the Intermediate Examinations in Arts and Science of London University, and for the Cambridge Higher School Certificate Examination, by kind permission of the Senate of London University and the Local Examinations Syndicate of Cambridge University respectively. Thanks are due to the Controller of H.M. Stationery Office for permission to reproduce a map included in Question 15 and based on a Daily Weather Report of the Meteorological Office. A few other alterations have been made to keep the text up to date, but diagram numbers and pagination of previous editions have been retained as far as possible.

J. B.

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INTRODUCTION TO

MAPWORK AND PRACTICAL GEOGRAPHY

PART I

CHAPTER I

OUR CONCEPTION OF MAPWORK AND OF PRACTICAL GEOGRAPHY RELATIVE TO MAPWORK. TYPES OF MAPS

1. INTRODUCTORY

The term "mapwork" may seem rather vague and generalised, but it is usually taken to comprise the study of various types of map, and consideration of the methods and principles underlying map construction.

We shall assume that the map is before us, and that in an elementary study of maps we are mainly concerned with an attempt to analyse it and to explain what it is intended to depict. It is with such aspect of mapwork that the earlier chapters of this book are concerned. Later chapters will deal with some aspects of map construction, including elements of the field-work on which maps, particularly large-scale maps, are based. In some respects this order may seem illogical. It might seem more logical at the outset to ascertain how a map has been made, or at any rate to link the details of construction with description and analysis. This is not expedient, because it is possible to use a map without knowing how it has been made, but such knowledge adds to the interest of map study and is required in more advanced examinations. Some examination syllabuses require merely study of certain maps, with no knowledge of the surveying methods necessary in the construction.

The second part of the book is concerned with certain aspects of map construction, which, when desired, can easily be correlated with earlier chapters. For instance, methods of contouring (Chapter XVII.) can readily be correlated with the study of contours on a large-scale map (Chapter IV.). In this book the term "practical geography" includes surveying and other details of map construction. It includes what is sometimes known as the "cartographical and diagrammatic representation of geographical data," in other words, the preparation of distributional maps and graphs founded on statistics illustrating some aspect of geography, such as climate, trade, crops, stock, or population (Chapter VIII.).

2. PROBLEMS OF MAP MAKING

All maps are representations on a plane surface of some part of the earth. On globes which represent the earth, distances and the relative position of places are reckoned with respect to certain lines known as parallels of latitude and meridians of longitude. (See Chapter XI. for explanation of latitude and longitude.) On the globe, such lines are circles. At the expense of sacrificing truth to a greater or lesser degree, it is possible to project them on to a plane surface, and a network known as a **graticule** or **projection** is the result. Such network is the basis of properly drawn maps, but there are many types of network, some of the most important of which will be treated in later chapters (Chapters XI., XII., XIII.).

The most important problems of *cartography*, which is the science of map making, are:—

(1) Selection of a suitable scale, which determines the size of a country on the map compared with its real size.

(2) Choice and construction of a projection.

(3) Cartographic representation, namely what to show and how to show it, particularly (*a*) the facts of physical geography concerning the relief and hydrography, (*b*) the facts of human geography, especially settlements and communications. Methods of cartographic representation should be designed to show as much as possible compatible with easy legibility. This is all bound up with the limitation of map representation due to scale, which is treated in the next chapter. A very important aspect of cartographic representation is lettering, which should be designed not only to produce the utmost legibility allowed by the scale, but also to emphasise the relative importance of physical features, towns, and political divisions.

(4) Use of colour, lithographic processes, and printing. Formerly maps were produced entirely in black, but now colour is largely used to show relief, water features, roads, vegetation, etc. Selection of suitable tints to show relief is an intricate matter, and when different colours are used a map is printed from many plates, each requiring a separate printing. Great skill and care are necessary to ensure proper correlation of the various colours and tints, and their correct relation to symbols and names which have been printed in black.

In criticising methods of representing facts on a map it is always necessary to consider, bearing in mind the limitations of the scale, what geographical facts should be shown and in what respects the map falls short of an ideal standard. At the end of Chapter VII. are hints for the critical cartographical examination of a map.

3. TYPES OF MAPS AND THEIR STUDY

Ordnance maps is the name applied to various types of British maps produced by the Ordnance Survey, which is manned largely by Royal Engineers, but is under the Ministry of Agriculture and Fisheries. Its Director is always a distinguished officer of the Royal Engineers. Ordnance maps were first made in the eighteenth century, and were based on surveys by Engineer officers, being intended for military purposes, such as defence against invasion. Chapters IV., V., VII., deal mainly with Ordnance maps, principally topographical ones and the larger-scale plans.

It is obvious that a large-scale map of even a small country would be very inconvenient for general use if printed on a single sheet of paper, and therefore such maps are produced on a series of related sheets, each one of which deals with only part of the whole area. One type of sheets, such as those of the British Ordnance maps, has rectangular bounding sheet-lines not related to the lines of latitude and longitude, so that sheets can generally be fitted together without much inconvenience, though sometimes neighbouring sheets overlap. In another type of sheets the sides are straight, but the top and bottom are curved, being bounded by curved parallels of latitude. These and the meridians are plotted for each sheet and only a limited number of sheets can be fitted together (see page 155).

The possibilities and limitations of scale cause maps to fall into various classes, each with distinctive characteristics. The largest-scale maps are sometimes known as **Cadastral maps.** They are really plans. The very large scale allows full detail to be given, such as the boundaries of fields, individual buildings, etc., and therefore these maps are useful for purposes of taxation or to define property in legal documents. The 6 inches and 25 inches to the mile Ordnance series are termed plans.

Topographical maps are large-scale maps founded on precise surveys, and show considerable detail of natural and man-made features. They are not on so

large a scale as cadastral maps, and cannot show detailed property boundaries. They are useful to motorists and walkers, to soldiers during manoeuvres and in wartime, and to geographers studying the regional geography of an area in some detail. The principal topographical maps of the Ordnance Survey are those on a scale of one inch, half-inch, and quarter-inch, respectively, to the mile. For the geographer, probably the most valuable maps are topographical maps, and it is with their study that this book largely deals. In a study of topographical maps it is necessary to examine the methods of representing relief and drainage, in order to obtain some idea of the physical features depicted. Knowledge of the various methods of representing relief and ability to visualise a three dimension picture of what they represent is necessary (see Chapter IV.). Especially important is ability to read **contours,** namely, lines on the map made up of all points which in the actual country are the same height above sea-level. A thorough grounding in some of the elementary principles of physical geography is indispensable if full advantage is to be derived from analysis of physical features shown on the topographical map. A chapter (VI.) endeavours to explain a few points connected with physical features such as stream valleys. Various symbols known as **conventional signs** are used by the cartographer to represent natural features such as marshes and cliffs, man-made features such as roads, railways, buildings. It is necessary to know them and to explain their presence, which can often be done by a consideration of the influence of physical features. Conventional signs are dealt with in Chapter IV., and their application is often apparent in the analyses of typical Ordnance maps (Chapter VII.). Much of the study of topographical maps should be devoted to interpretation of land forms and their influence on human geography, such as the distribution and character of settlements, and the development of communications.

Foreign Maps.—This book deals essentially with British maps, but after studying these the student may care to examine some foreign maps similar to them in scale and purpose, and to make comparison. Foreign countries which use the metric system find a scale of one-inch to the mile inconvenient, and for maps corresponding to our one-inch series have adopted a scale of 1 : 50,000, which is approximately one-and-a-quarter inches to the mile. Approximately, a scale of 1 : 100,000 corresponds to our half-inch and a scale of 250,000 to our quarter-inch. A scale of 80,000 (nearly $\frac{3}{4}$ inch to the mile) is used on some maps, especially on a French series. Some foreign maps, particularly the French

1 : 50,000, show more varied detail than ours, and some show features which do not occur in Britain, as the glaciers of Switzerland.

An important map is the **International map,** which, with the co-operation of various countries, was designed to produce a uniform map of the World, divided into sheets uniform in scale, size, shape, and style of drawing. Chapter IV. of Hinks' *Maps and Survey* has a helpful description and criticism of the International map. Chapter V. deals with " The maps of Europe," and Chapter VI. with " Other foreign maps "; both chapters give analyses of typical sheets on various scales of the official maps of foreign countries. French, German, and Swiss sheets on the scales noted above will repay study.

ATLAS MAPS.—Atlas maps are on a smaller scale than topographical maps, and generally show details condensed and generalised from such maps. Few atlases have a scale as large as 1 : 1 million (nearly 16 miles to the inch), but in *The Times Survey Atlas of the World* the maps of France and Germany, each covering several sheets, are on this scale, and the British Isles sheet-maps of this atlas are on even a larger scale, namely 1 : 633,600 (10 miles to the inch). *The Times* Atlas maps are much larger than those of the ordinary school atlas. It is a work of reference, and there are a few foreign atlases similar in scope.

To-day the best school atlases, despite their limitations of space and the necessity of keeping the price within a reasonable limit, are compiled on logical and scientific lines. Maps of the world showing relief, vegetation, climatic data, or ocean currents, ought to be drawn on the most suitable projection, and though sometimes improvement could be suggested, a good modern atlas usually shows wise choice of projections. The continents and the larger countries often have a physical map and a political map on opposite pages, drawn on the same graticule and scale, so that the political map can be read in the light of physical factors. Where two such maps are not deemed possible, boundaries, routes, railways, and other political details are usually shown on a colour-layered relief map, and if some overcrowding does result, such a map is better than the purely political one. Some atlases give distributional maps, sometimes of crops or natural vegetation, of occupations or mineral deposits, but such maps are not always based on quantitative statistical data and are too generalised to be anything more than a broad guide as to the location of, say, temperate grassland (often largely under cultivated crops), or the rice-lands or rubber plantations of the tropical zone. It is not easy to make a good distributional map on a small scale.

DISTRIBUTIONAL MAPS.—Maps which, with the aid of certain symbols or shading schemes, show the distribution of crops, stock, or people in a given area are known as **Distributional maps.** Such maps dealing with crops, stock, or minerals are sometimes termed **Commodity maps.** The distribution may show actual figures, generally expressed in round numbers, or may show numbers of stock or people per square mile or per 1,000 acres, or percentage of area under any specified crop. In Chapter VIII. the various methods of making distributional maps, with their respective advantages and disadvantages, are discussed.

WEATHER AND CLIMATE MAPS.—Each day **Weather maps** are prepared for that day by the Meteorological Office in London from data founded on observations made at various observing stations. They deal mainly with temperature, pressure, winds, and rainfall, and in addition to showing the general weather conditions of the British Isles and adjacent regions at a specified time, form the basis of a weather forecast for the succeeding twenty-four hours. Various symbols (see page 95) are given on each weather map to indicate certain aspects of weather. Study of weather maps includes ability to read them and to describe the current weather conditions, as well as to suggest likely developments in the near future. Weather maps dealing with their own local conditions are issued by the larger European countries, the United States of America, Canada, Australia, etc. If a few specimens of any such maps can be obtained, much benefit will result from their study and comparison with the British maps.

Weather maps deal with conditions at a specified instant of time, **Climate maps** with the sum total of weather conditions spread over a longer period, for instance, a month or a year. The data for weather maps are absolute, that is, conditions which were actually observed at the time in question. Climatic data are generally averages for a considerable number of years or months as the case may be. A map showing January temperatures would be based on the average figures for the Januaries of as many years as possible. A mean annual rainfall map would be based on the average rainfall of many years. A weather map usually shows the various elements of weather on the same map, for instance, temperature, pressure, winds, rainfall. A climatic map is more specialised, that is, there are generally separate maps for temperature, pressure, rainfall, etc. Given a set of such maps for January and July, usually (in the Northern Hemisphere) the coldest and hottest months, or better still, for January, July, October, and April, representative of each season, it is possible to build up a generalised

description of the climate of a region. Weather may be compared with the news in a daily newspaper, climate with the summary of a year's events.

Publication of British weather maps was suspended during the War of 1914-18, and again in 1939, and the subsequent war years.

GEOLOGICAL MAPS.— Some maps show the distribution of different rocks, usually in combination with contours, so that they guide us in interpreting physical features and in tracing their evolution: such maps are called **Geological maps.** They are useful aids in the study of physical geography. Chapter XVIII. is a very elementary guide to the reading of some of the more common features of such maps. Geological maps of newly developed colonies are very important as guides to mineral wealth and soils. Government geologists, on whose surveys such maps are based, perform very valuable work, especially where mineral deposits or artesian water may make all the difference between a district being developed and settled or left derelict. Geological maps should be made on the basis of topographical maps. The geological data of such maps must be inserted upon a previously constructed topographical map.

NATIONAL ATLAS.— The Ordnance Survey have a series of maps entitled the "National Atlas." They are on the scale of 1 : 625,000, or approximately 10 miles to the inch. Great Britain is covered by two sheets (*a*) Scotland, with that part of England north of Kendal; (*b*) remainder of England with Wales. The series includes a topographical base map for (*a*) and (*b*), and maps covering some particular aspect of geography. Separate maps deal with administrative areas, topography, physical features, solid geology, drift geology; igneous and metamorphic rocks; limestones, sandstones, sand and gravel, each of these formations being assigned a separate map; land utilisation; land classification; grasslands; types of farming; electricity transmission lines; electricity supply areas; coal and iron; iron and steel; roads; ports; population density; population changes based on the census of 1921 and 1931, and estimates for 1939.

Most of these maps have been specially prepared under the direction of Dr. E. C. Willatts in the Maps Office of the Ministry of Town and Country Planning, and in the Maps Office of the Department of Health for Scotland, but some have been compiled by other departments or research organisations.

The two Maps Offices have intensively examined a great amount of information, much of it unpublished, and charted the results on large-scale manuscript maps, from which has been drawn the above series of "National Atlas" maps.

CHAPTER II

SCALES: THEIR MEANING, USE, AND CONSTRUCTION

1. THE MEANING OF SCALE

'**Scale** has the meaning of a ratio. It signifies the proportion which a length on the map bears to actual distance on the ground. To speak of the scale of one inch to a mile means that if we measure one inch as the distance between two churches shown on the map, this distance would be a mile in the actual country.'

If the earth were perfectly flat, such a definition would apply without any qualification. The earth, however, is not flat. On a small globe try to paste a tiny piece of paper to cover, say, Denmark. It would probably not pucker and would remain flat. Now try to cover Europe or the Americas with a larger piece of paper. This would show wrinkles and creases, and might require folding to make it fit on the globe. Small-scale maps of large areas suffer most from errors of scale, and large-scale maps of small areas least, in fact, very little for practical purposes.

It is not possible that the scale of any map should be correct in all directions. Some projections, however, give correct scale in certain directions, as along particular parallels and meridians. On other parts of the map the scale may not be true.

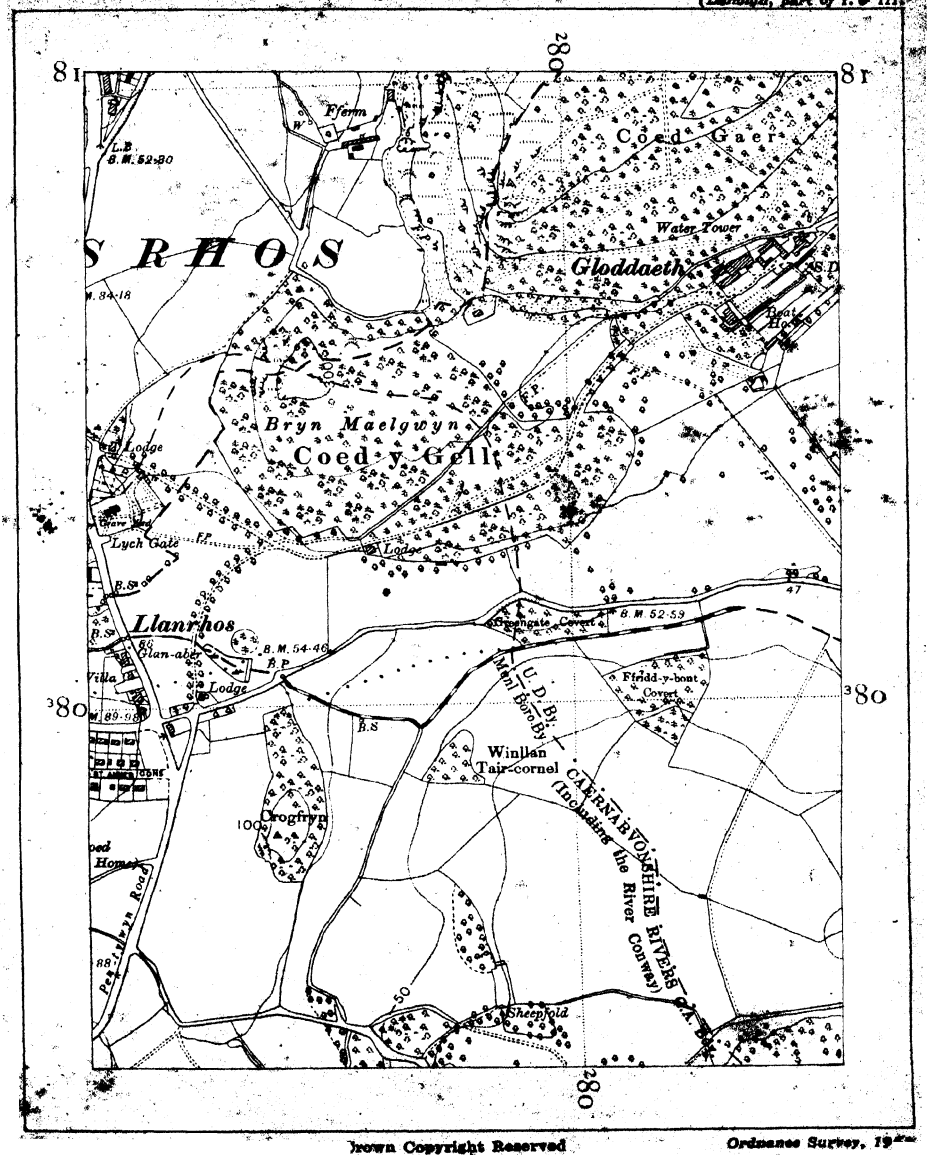
'In determining scales it is necessary to bear in mind the purpose for which the map is intended, as well as the amount and the character of the detail to be shown. Town plans require a large scale in order to show the outline of buildings. An atlas map designed to show the general distribution of high land and low land need not be on so large a scale.'

2. USE OF SCALES

It is essential that on any plan or map there should be some indication of the scale in order that distances may be easily calculated. There are various ways of indicating scale. In British maps the scale is indicated by one of two common methods.

(1) By direct statement of so many inches to a mile or so many miles to the inch.

SIX INCHES TO ONE MILE (Prov. Edn.) A small portion of {Caernarvon V. N.W. / Denbigh, part of I. & III.}

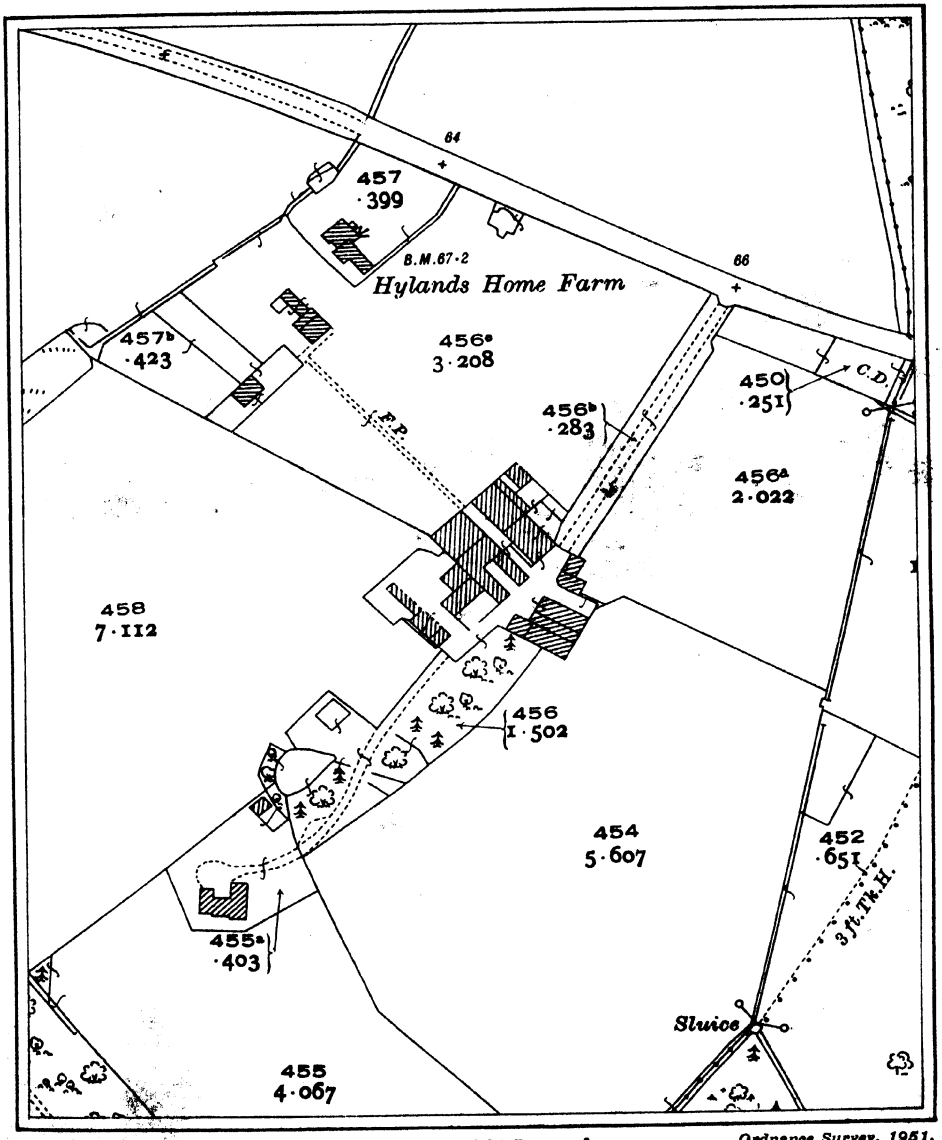


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Ordnance Survey, 19

TWENTY-FIVE INCHES TO ONE MILE.

A small portion of Sussex (East) LXVIII. 4.



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Ordnance Survey, 1951.

(2) By use of a fraction whose numerator, 1, indicates the length on the map, and whose denominator indicates the length in the actual country. Thus the fraction $\frac{1}{63360}$, sometimes written 1 : 63,360, indicates the scale of one inch to a mile. There are 63,360 inches in a mile, and the fraction signifies that one inch on the map represents 63,360 inches in the real country. Such a fraction is called the **Representative Fraction.** This method is very useful where a map may be consulted by people outside the country for which it is primarily intended. A Frenchman unfamiliar with English measures might not be very confident in calculating distances from a map which was labelled with a scale of six inches to a mile. But tell him that the scale of this map is $\frac{1}{10560}$ and he can use it readily, because this method is employed for his own country's maps. He would not think in English measure, but in metres, with the decimal notation to which he is accustomed. Thus, $\frac{1}{10560}$ to a Frenchman would mean 1 cm. to 10,560 cm., etc.

The following simple rules are useful:—

(1) *Given the Representative Fraction, to find* (*a*) *the number of inches to the mile,* (*b*) *the number of miles to an inch.*

(*a*) Divide 63,360 by the denominator of the fraction,

e.g. if R.F. is $\frac{1}{10000}$, then $\frac{63360}{10000} = 6{\cdot}336$ (6·34 approx.) inches to 1 mile.

(*b*) Divide the denominator of the fraction by 63,360,

e.g. if R.F. is $\frac{1}{316800}$, then $\frac{316800}{63360} = 5$ miles to 1 inch.

(2) *Given the number of miles to the inch, to find the Representative Fraction.*

Multiply 63,360 by the number of miles to the inch in the given scale, and you will have the denominator of the R.F., *e.g.* 4 miles to the inch

$$= 1 : 63{,}360 \times 4 = \frac{1}{253440} = \text{R.F.}$$

(3) *Given the number of inches to the mile, to find the Representative Fraction.*

Divide 63,360 by the number of inches to the mile in the scale, and you will have the denominator of the R.F.

E.g. If the scale is 4 inches to the mile, denominator of R.F. is

$$\frac{63360}{4} = 15{,}840, \text{ and R.F. is } \frac{1}{15840}.$$

It is convenient to note the following tables:—

R.F. FROM SCALE.

Scale-Inches to the Mile.	R.F.
$\frac{1}{4}$	$\frac{1}{253440}$
$\frac{1}{2}$	$\frac{1}{126720}$
1	$\frac{1}{63360}$
6	$\frac{1}{10560}$

SCALE FROM R.F.

R.F.	Scale-Inches to the Mile.
$\frac{1}{10000}$	6·34 (approx.)
$\frac{1}{50000}$	1·27

R.F.	Scale-Miles to the Inch.
$\frac{1}{100000}$	1·58
$\frac{1}{250000}$	3·95
$\frac{1}{500000}$	7·89

3. PLAIN SCALES

On maps, in addition to the statement of scale or indication of the Representative Fraction it is convenient to give what is known as a **plain or linear scale.** This is merely a line conveniently subdivided so that distances on the map can easily be read from it by using a piece of cotton or dividers. A plain scale should be long enough for measurements to be reckoned from it easily, and it should represent a convenient round number of the unit selected so that subdivision is facilitated.

EXAMPLE

Construct a plain scale for 6 ml. to the inch. (See Fig. 1.)

By the given scale 5 in. represents 30 ml., giving six primaries. Take another 5 ml. to divide amongst the secondaries.

If 5 in. represent 30 ml., we must determine how many inches represent $30 + 5 = 35$ ml., *i.e.* $\frac{35 \times 5}{30} = 5{\cdot}83$ in.

Draw a line AB, 5·83 in. long, divide it into seven parts, and subdivide the left-hand side part into 5 smaller parts of 1 ml. each. The method is as follows:—

From A draw AC rather longer than AB and making an angle not more than 30° with AB (a larger angle might lead to inconvenience in drawing). On AC, with dividers, from A mark 7 points *m*, *n*, etc. (the same number as the required divisions of AB) at equal distances, which may be approximately $\frac{1}{7}$ of AB. Join *t*, the last point, to B, and from the other points draw lines parallel to *t*B. These parallel lines cut AB and give the required divisions.

The first division can be subdivided into 5 equal parts by the method indicated.

Some people think a graphical method of drawing a scale unnecessary. If they wished to show, say, 2,100 yards on a scale of 5 in. to 1 mile, they would possibly work the sum $\frac{2100 \times 5}{1760} = 5{\cdot}96$, and then make use of a suitable ruler.

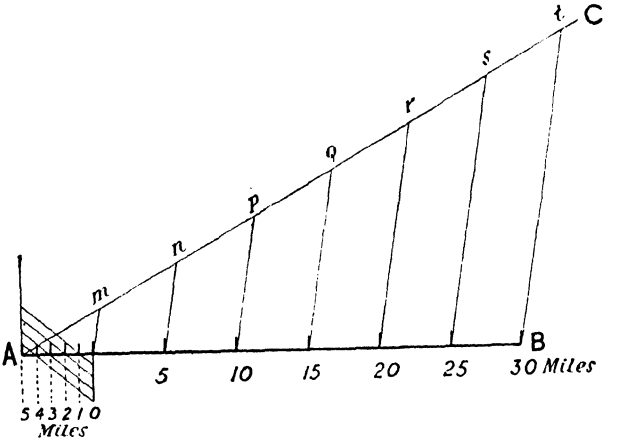


Fig. 1. To Divide a Line, 5·83 In. Long, into 7 Equal Parts to Give a Plain Scale to show 6 Ml. to the Inch.

A diagonal scale is given on some protractors and rulers. Its use will be seen from Fig. 2. When the dividers are in the position *xx'*, it is obvious that the measurement is 1 inch and nine-tenths, *i.e.* 1·9. If we move the divider points *x*, *x'*, one space up, it becomes 1·91, two spaces up 1·92, three spaces up 1·93, and so on. When they are in position *yy'*, the measurement is seen to be more than 2·5 in., but less than 2·6 in. The divider point *y* is on the sixth horizontal line from the bottom, hence the measurement is 2·56 in. The distance to represent every 100 yards of the scale noted in the preceding paragraph is 5·96 divided by 21 = 0·28

approximately. For this, the positions of the divider points are indicated by crosses on the diagram.

Reduction and enlargement of maps will emphasise the significance and the limitations of scales. Not only is less detail possible on a small-scale map, but

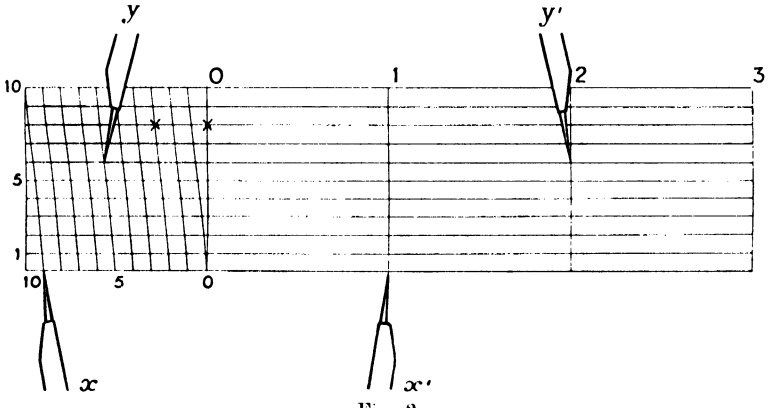


Fig. 2.

the details, notably rivers and roads, must be shown in a very generalised way, and frequently of a size out of proportion to the scale.

It is interesting to reduce maps to a smaller scale and to see how far the detail can be retained without sacrifice of legibility. The method is quite simple. Take the two scales to represent a fraction, thus

$$\frac{\text{Old scale}}{\text{New scale}} = x.$$

Divide the original large-scale map into squares of, say, one inch side, and draw a new outline with similar arrangement of squares, the sides of which must be $\frac{1}{x}$ of the original. Then sketch in as much detail as possible.

To enlarge a map, each square in the new outline will be x times that of the original. Sketch in detail as above.

Throughout this chapter the use of the word "scale" has been applied to *horizontal scale.*

CHAPTER III

THE VARIOUS USES OF MAPS IN THE FIELD

1. USES OF MAPS

Given a map, it is well to ask: "What are its uses, and by whom is it likely to be used?" Different people will assign different values to large-scale topographical maps. To the touring motorist, the most prominent features will be the roads and the towns or villages where a halt may be made at some suitable hotel. The mountain climber may be most interested in contours as depicting the heights to be conquered. The soldier, during manoeuvres or in wartime, is concerned with topographical information likely to be useful while on the march, or as a guide to bivouac, cover, or site for entrenching work.

Such users of maps are mainly concerned with use in the open air, in the actual country mapped, and there are certain elementary principles which they must observe if full benefit is to be derived from their maps. A knowledge of the use and application of scales[1] is necessary, as well as familiarity with the conventional signs[2] which indicate various features. Methods of showing relief[3] or difference between high and low land must be understood and interpreted.

From the academic point of view of a university student in the map-room, there are several other aspects of the map. He will make much use of maps in outdoor excursion work, in connection with his practical mapwork course, and as an aid to realistic study of physical geography and geomorphology. He must be familiar with the principles and methods which underlie the making of maps, and he must be able to use them practically. In many respects, though adapted to his own particular needs, his outlook will resemble that of the motorist, the walking tourist, or the soldier. He must be able to find his way from place to place, and to recognise various features, especially those which are associated with physical geography. But his outlook is based on deeper foundations than that of the mere user of maps. He must be so familiar with maps and what they signify that, in the map-room or study, a topographical relief map will enable him to visualise the actual country depicted on the map.

[1] See page 8. [2] See page 24. [3] See page 19.

Maps have been termed "the geographer's shorthand," and a geographer should be able to transcribe and to interpret the whole of the notes comprised in such shorthand. Given an Ordnance map, he must readily (1) suggest suitable physical divisions, (2) trace the relation between physical features and the development of human settlement, and (3) possibly build up a synthetic geographical description of the area.

We shall suggest how these and other aspects of map study may be developed.

2. SETTING A MAP

A somewhat mechanical, but very important, aspect of map-using is ability to identify our position in the country in relation to the position on the map corresponding to our actual location. To do this properly is to be proficient in what is known as **setting the map.**

To set a map is to adjust it so that the North point of the map corresponds with North in the actual country. Here it is desirable to consider the meaning of bearing and to note the difference between true North and magnetic North.

The **bearing** of an object refers to its direction with reference to the observer. It is measured by the angle formed by (1) a fixed line through the observer's position, and (2) a line from the observer's position to the object observed. It should be very carefully noted that bearings are taken from the North, and in the same direction as that in which the hands of a clock move. Stated more formally, this can be expressed by saying that any bearing is measured in a clockwise direction, and it is obvious that this cannot exceed 360°, the number of degrees in a circle.

A **true bearing** is the angle which a line from the observer's position to the object observed makes with the true North-South line. A **magnetic bearing** is the angle which a line from the observer's position to the object observed makes with the magnetic North-South line at the place. Both true and magnetic bearings conform to the general rule for measuring bearings in a clockwise direction.

It is necessary to explain the meaning of *magnetic* North-South line. The magnetic compass needle does not point to true North, but to what is known as the magnetic North Pole. This is not a fixed point. It moves very slowly from day to day and year to year. The angle between the true and magnetic North-South lines is known as **variation of the compass,** or **magnetic variation,**

but is not the same at all places. The angle *a* in Fig. 3 represents this variation or declination of the compass west of the true North-South line, and if it is known it is easy to convert true bearings into magnetic bearings or vice

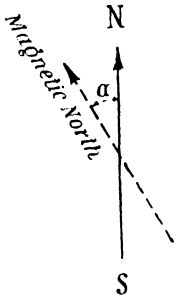


Fig. 3. True and Magnetic North-South Line.

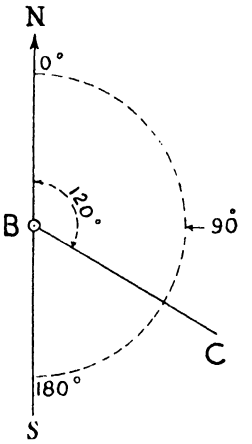


Fig. 4. To Obtain True Bearing from a Map.

To find bearing of church tower C from point on bridge B where the observer stands, draw a true North-South line through the position of the bridge (B) on the map. Join B to the position of the church (C). With protractor (shown by dotted line) read angle NBC, which is 120° and is the forward bearing from the bridge to the church tower.

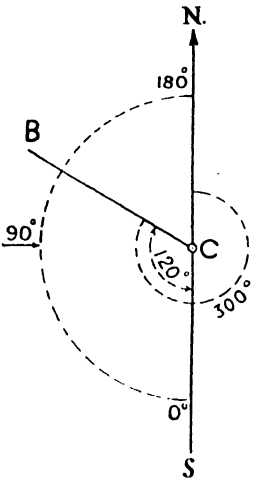


Fig. 5. To Obtain True Bearing from a Map.

To find the bearing of the bridge (B) from the church (C) draw the true North-South line through C and join the position of the church (C) to that of the bridge (B). Read the angle SCB = 120° and add to 180° (representing the straight angle NCS = half a complete turn). This gives 300° as the bearing of the bridge from the church.

Note that all bearings must be reckoned clockwise from the North.

versa. In Britain declination is *west*. To convert true bearings into magnetic bearings, add the variation; to convert magnetic into true bearings, subtract the variation.

Maps showing the magnetic North-South line usually say for what year the declination is reckoned, and thus up-to-date correction is possible. In 1946

declination varied from about 8° in extreme S.E. England to about 15° in the northern Hebrides. It is decreasing by about 10′ annually.

The recording of magnetic variation was formerly done at Greenwich Observatory, but in 1925 the work of recording earth magnetism was transferred to Abinger, near Dorking in Surrey.

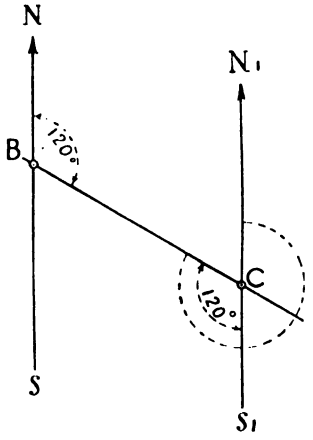


Fig. 6. Illustration of Back Bearings and the Conversion of Forward into Back Bearings.

Through C draw N_1CS_1 parallel to NS. Forward bearing of C from B is 120° (*i.e.* angle NBC). Forward bearing of B from C is reflex angle $N_1CB = 300°$, but this is the back bearing of C from B, and is equal to 180° + 120° (*i.e.* 180° + angle BCS_1).

Because N_1S_1 is parallel to NS, angle BCS_1 = angle NBC. This can be applied to Fig. 5.

Bearings are read with the Prismatic Compass on the ground, but from a map true bearings can be obtained with a protractor by the method noted in Fig. 4. Bearings from the observer to any object in the field are known as **forward bearings.** Bearings from the object to the observer are termed **back bearings.**

To obtain back bearings, if the bearing is less than 180° add 180°, if the bearing is greater than 180° subtract 180°. (See Fig. 6.)

3. METHODS OF SETTING A MAP

Four methods of setting a map are given below:—

(1) By Compass.—North, both true and magnetic (see page 14) is generally shown near the top right-hand corner of British topographical maps. Lay the map flat on the ground and place the compass on the map so that its axis, the 0°–180° line, is on the magnetic North-South line. Then gently rotate the map until the magnetic North-South line coincides with the compass needle. If magnetic North is not shown on the map used, it may be possible to determine it if you know the variation of your compass for the place. If the top of the map represents true North, by means of a protractor it is possible to make with the true North-South line an angle representing your compass variation at the place. The arms of this angle are respectively the true and magnetic North-South lines. Having thus found the magnetic North-South line, you proceed as described above. If a protractor is not available, lay the compass along the true North-South line on the map, and rotate the map until the compass needle is the same number of degrees east or west of the true North-South line as represent the variation.

(2) By the Sun.—Assume the Sun at noon is due south in the N. Hemisphere, and in relation to a circle changes its position 15° per hour. Find the correct time of day, being careful to make adjustment when "summer time" is in operation. Then, with a protractor mark off with the North-South line measuring clockwise from north an angle containing 15° for every hour after midnight. At the end of the line thus made, stick up a large pin or hold a pencil vertically. Turn the map until the shadow of pin or pencil is cast on this line, and the map is set. (See Fig. 7.)

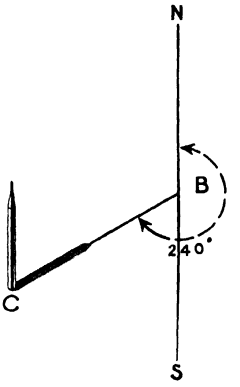


Fig. 7. To Find the NS Line from the Sun.

Let NS be the North-South line. If it is 4 p.m. o'clock make the angle NBC 240° (15° for every hour after midnight). At C hold pencil vertically, rotate map until shadow of pencil is shown on the line CB, then NS is in true position.

True South can be approximately found at any time during the day when the Sun is observable, and thus North can be determined. A watch showing local time is required. Hold the watch face upwards in a horizontal position on the palm of the hand, and turn the watch until the hour hand points to the Sun. The line bisecting the angle made by the hour hand and a line from the dial centre to twelve o'clock points to South. This applies to the Northern Hemisphere. (See Fig. 8.) For the Southern Hemisphere, if a line joining the dial centre to twelve o'clock is pointed at the Sun, the bisector of the angle made by this line and the hour hand points to North. (See Fig. 9.)

Limitations of the above methods should be recognised. Only at the equinoxes does the sun change position uniformly at 15° per hour.

(3) By Comparison with Straight Lengths of Features.—These should be easily identifiable features, such as a road, railway, canal or other watercourse, *e.g.* the road or railway from Draycott to Cheddar on the map facing page 32, or the straight length of the River Yeo on the same map. The map should be held so that the feature on it is as nearly as possible parallel to the feature in the field. Then North on the map should be noted, and the direction of North in the country taken accordingly.

(4) By Association of Features on the Map and in the Country.—Select two prominent features depicted on the map, such as a church spire and a railway bridge. Lay a pencil or ruler on the map to connect the two features, and turn

the map until the pencil is parallel to the imaginary line joining the features in the actual country. North is now easily determined by comparison with the North point on the map, which can thus be set with reasonable correctness.

When a map is set, features on it and in the actual country are in their relative positions, but it must be remembered that the map is on a comparatively small scale, and that the estimation of actual distance is not always easy.

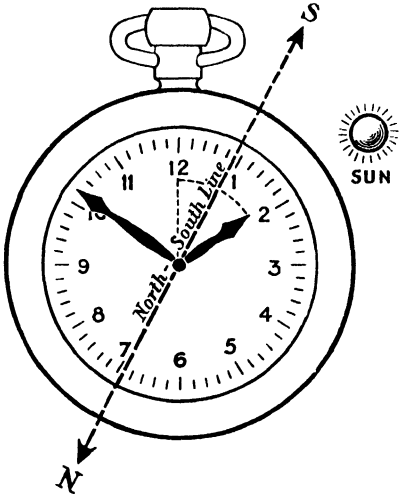


Fig. 8. To Find by Watch South in Northern Hemisphere.

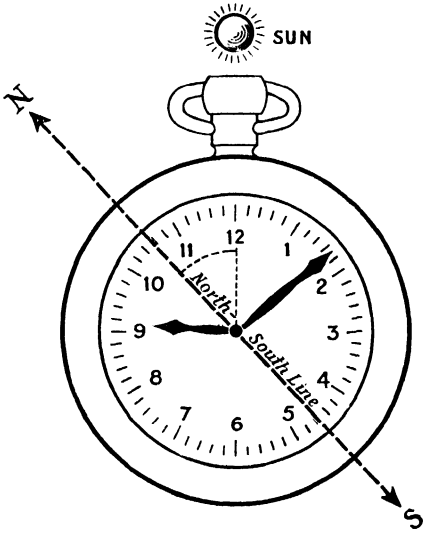


Fig. 9. To Find by Watch North in Southern Hemisphere.

Having set the map, it is desirable to identify your position on it. With a good topographical map on a reasonably large scale, say one inch or half an inch to the mile, this is not difficult in ordinary inhabited country such as East Anglia, where villages are numerous, and where features such as cross-roads, churches, woods, assist identification. In mountainous or open moorland country where there are few features denoted by the ordinary conventional signs, exact determination of your position is less easy, and it may be necessary to employ the methods known as resection and adjustment, which are explained in Chapter XV., dealing with plane-tabling, an aspect of survey work. At present you need not trouble to understand these methods.

CHAPTER IV

PRELIMINARIES TO MAP READING: TYPES OF ORDNANCE MAPS

1. METHODS OF SHOWING RELIEF

CONTOURS.—A contour is a line made up of all points having the same altitude above mean sea-level. It represents the line of intersection between a horizontal plane and the surface of the country. Complete contours must be regarded as closed curves, which cannot cut each other. If the ground is very steep, contours may converge to give a single line, and may run together as such to represent a very steep slope, but they will diverge when the slope becomes gentler. The level represented by one converging line is vertically above the other on the actual cliff. Hence superposition of one contour on the other on the map is logical.

Contours are the results of survey with instruments which give the height above sea-level of certain points observed on the ground. (See Chapter XVII.) Such are not always the highest parts of a ridge or hill, but can be on the floor or slopes of a valley, where it may be necessary to have absolute heights as a guide to accurate contouring. Sometimes, on the map, lines are sketched approximately between contours based on actual observation with instruments, and are known as **form lines.** To some extent they may assist map reading where actual contours do not exist, but they are only approximate, and might be misleading if well-developed minor features occur in the country between what are positions of contours on the map. Form lines are generally broken, whereas contours are continuous.

Contours are the most important means of showing relief, and form the basis of most other methods used for this purpose. Most maps of the Official Surveys of Britain, her colonies, and of the principal European countries use contours. Exceptions are very small-scale maps and very large-scale maps intended primarily for estate purposes or as town plans. British maps use the foot as the unit of the vertical interval, *i.e.* the interval between successive contours, but most foreign countries employ the metre. Great variety of interval is employed and frequently certain contours, say, every fifth or tenth contour, are thickened to facilitate reading. Examples are British, U.S.A., Swiss, and French maps for

regions with considerable altitude. Most contoured maps show a goodly number of isolated spot heights, which are of great assistance in helping the visualisation of minor features.

Contours should be numbered so that the figures are on the upper side of the contour. This method enables uphill and downhill readings to be made more easily. On some of the latest Ordnance maps, numbers are inserted in " broken " contours, a method less easy to read than that named above.

BENCH MARKS.—Marks, known as bench marks, are placed on buildings, walls, etc., recording their height as determined in levelling operations. Formerly bench marks were cut into the actual brick or stone. Now they are cut on bronze plates let into the wall and flush with its surface. The height refers to the bench mark and not to the ground, so is not the same as a spot height.

TRIGONOMETRICAL STATIONS.—These are sometimes shown with their height. They are points on the earth's surface where angles of a triangulation (see Chapter XIV.) are measured. A triangulation is a survey which divides a country into triangles for the purpose of survey. Trigonometrical stations are shown by a small triangle on one-inch maps, and on six-inch and twenty-five-inch plans. Spot heights without this triangle are not trigonometrical stations.

HILL-SHADING.—A light is imagined to be over the region and to cast shadow in some parts, to illuminate others. One method imagines that the light is vertical over the land, and that the steepest slopes are lit up the least. Thus the sides of hills and mountains are shaded dark, while relatively flat land, such as valley bottoms, plateaux, hill-tops, and mountain peaks, is of lighter tint. Another method imagines that the light shines from the north-west of the area, thus casting shadow over the eastern and southern slopes of higher land. Hill-shading does not show absolute heights. Relative heights are not very clearly indicated, nor are gradients, which are so well shown by contour lines. Usually it is not easy to determine from hill-shading what is uphill and what downhill. The same drawback is associated with hachures. Hill-shading does, however, give a general idea of the relief of a country, and is suitable for smaller-scale maps, as the four miles to the inch, and the ten miles to the inch of the British Ordnance Survey.

HACHURES.—These are short lines which are supposed to indicate the direction water would take if flowing from high ground to low. For steep slopes the hachures are closely spaced, for gentle slopes they are wider apart and are thin, but flat ground

is not shaded in any way. It is necessary in hachured maps to have plenty of spot heights in order to ascertain the approximate altitude. Hachuring does not clearly indicate absolute heights, and this limitation, as well as the drawback of closely-packed and not very legible hachures in mountainous country, has made the method lose favour with modern map-makers. It was one of the earliest methods of showing relief, and was favoured by Napoleon Buonaparte. It was used on most standard maps during the nineteenth century, and some of these older standard maps are still in use, notably the 1 : 80,000 map of France.

Contours are sometimes supplemented by hachuring or by hill-shading, the auxiliary methods being useful to show minor features which would be lost if only contours were used, especially when the contour interval is fairly large. The British one-inch and half-inch maps have editions where hachuring and hill-shading are respectively combined with contours.

LAYER TINTS.—Either colours or different methods of black and white shading are used in combination with contours, especially in atlas maps. Examples of the method for larger-scale maps are the famous International map on the scale of 1 : 1,000,000, and certain layer-tinted Ordnance maps, especially the layered quarter-inch and half-inch maps. Various shades of green for low, brown for higher, and pink for very high land are used in the colour method. A great advantage of the method is that distribution of high and low land can be readily grasped. Objections are that in very high country tints may be so dark as to make the insertion of legible detail impossible. When contours are very close, layer tints do not conduce to clarity. The layer method is very useful for showing on small-scale maps the absolute and relative heights of the principal physical features.

2. ONE-INCH ORDNANCE MAPS

Probably the most familiar Ordnance map is that on a scale of one inch to the mile, or representative fraction 1 : 63,360. There are various styles and editions of this map. That of 1931 is termed the Fifth (Relief) Edition. The contours are for intervals of 50 ft., and by means of hill-shading and layered tints, the appearance of a model with three dimensions is secured. Sheets of the Fifth Edition were also produced without the hill-shading and layered tints. The New Popular (Sixth) Edition (published 1946-7) differs in a few symbols, but mainly in including the National Grid system for reference (see p. 154).

Previous to 1892 the Ordnance maps were printed in black, with the exception of brown hachures, but in 1892 a new edition was produced, in which streams and other water features were in blue, the roads in brown, contours in red, with brown hachures. This edition lasted until the issue of the Popular (Fourth) Edition.

After the War of 1914-18 the Popular Edition was published. Legibility was a main consideration, certain details of previous editions, such as hachures, being omitted with a view to avoiding overcrowding. Contours with 50 ft. intervals were introduced, and considerable care was taken to make the relief features prominent and easy to read. Judicious use was made of colour, especially with respect to rivers, woods, and roads, but the roads were vividly coloured, and thus made more prominent than railways, which, perhaps, was not a bad thing from the practical standpoint, as Ordnance map users generally wish to know more about roads than about railway routes.

On the current one-inch maps, towns, villages, hamlets, isolated farmsteads, roads, footpaths, railways, stations, woods, parks, and country seats, rivers, canals, lakes, county and parish boundaries, are shown, with many features applicable to certain districts, such as cliffs along the coast as at Brighton and Flamborough, beacons along parts of the coast, windpumps for raising water in dry regions such as chalk country.

Some large sheet tourist edition maps on a scale of one inch to the mile are obtainable. Those for the English Lake District, the Peak District of Derbyshire, and the Trossachs of Scotland are specially recommended for study. They afford good practice in the study of relief features of considerable variety, and the general geographical aspect of these regions is varied. They combine colour layering with contours.

3. HALF-INCH AND QUARTER-INCH ORDNANCE MAPS

The smaller-scale maps, namely the so-called quarter-inch and half-inch maps, on a scale of four miles and two miles to the inch respectively, are on the lines of the one-inch maps, but the relief is not shown in such clear detail, and other features are on a smaller scale. They are, however, useful maps, and should be studied along with the one-inch maps. This will enable comparison to be made and will give exercise in the appreciation of the purpose of scales. Relief is indicated by means of contours and layer colouring; water features are shown in blue.

The large sheets of the revised Fourth Edition of the quarter-inch maps give a very graphic general picture of a considerable extent of country. Sheet 6,

which is entitled "North Midlands and Lincolnshire," includes Leeds and Bradford in the north; Burnley, Manchester, and Stafford in the west; Leicester and Oakham in the south; King's Lynn, Grimsby, and Hull in the east; and thus affords excellent contrast between the higher land of the Pennine-Peak region and the lowlands of the Fens and coastal marshland. The black of the habitations stands out very clearly, especially in the larger towns, which, with the vividly coloured roads, illustrate the meaning of nodality. Continuation of the roads, with their Ministry of Transport numbers, and indication of direction in the margin off the map, is a very useful feature.

There is an excellent Ordnance Survey Atlas of England and Wales and one of Scotland, in which maps based on the quarter-inch sheets of the layered edition are mounted and bound in atlas form, with a serviceable index. These atlases are rather costly, and not everyone desires or can afford sheets covering the whole country.

4. *MEDIUM AND LARGE-SCALE SHEETS. (Examples opposite page 8.)

Of medium-scale sheets, the six-inch series is very useful and well known. Contours up to 1,000 feet are at 50 ft. intervals, but above 1,000 feet the 250 ft. vertical is used. The contours are shown in red. Contours at 50 and 100 ft. vertical intervals were determined by actual survey with instruments, but in some sheets, notably for certain counties in northern England and southern Scotland, sketched contours, or form lines, for 25 ft. intervals are inserted. These maps are not coloured, and because of the black printing, features sometimes are not easy to follow without considerable practice.

Maps on a scale of 25 inches to the mile are intended to give the detail of a plan, and are useful to the landowner and farmer. Field boundaries are clearly shown, and some sheets indicate the area of enclosures. The map is published for the cultivated districts of Great Britain, and the fact that it is not available for uncultivated districts explains its function. The 25-inch plan shows hedges and fences, but the real boundary of property is often some little distance beyond the hedge. Hence this is not literally a cadastral map in the same sense as a French **cadastre,** although it is frequently known as a cadastral map.

Sheets on a scale such as 60 inches to the mile or a scale of 1 : 500 (= 126·7 inches to the mile) are really plans, and are issued for towns only. The largest scale is sufficient to show details of buildings, such as thickness of walls, with levels along the principal streets. Features connected with public service, such

* The O.S. now term the 2½ inch (see p. 25) and 6 inch series "medium" scale sheets.

as water-supply, lighting, and drainage, are shown, for example, hydrants, lampposts, manholes, gulleys.

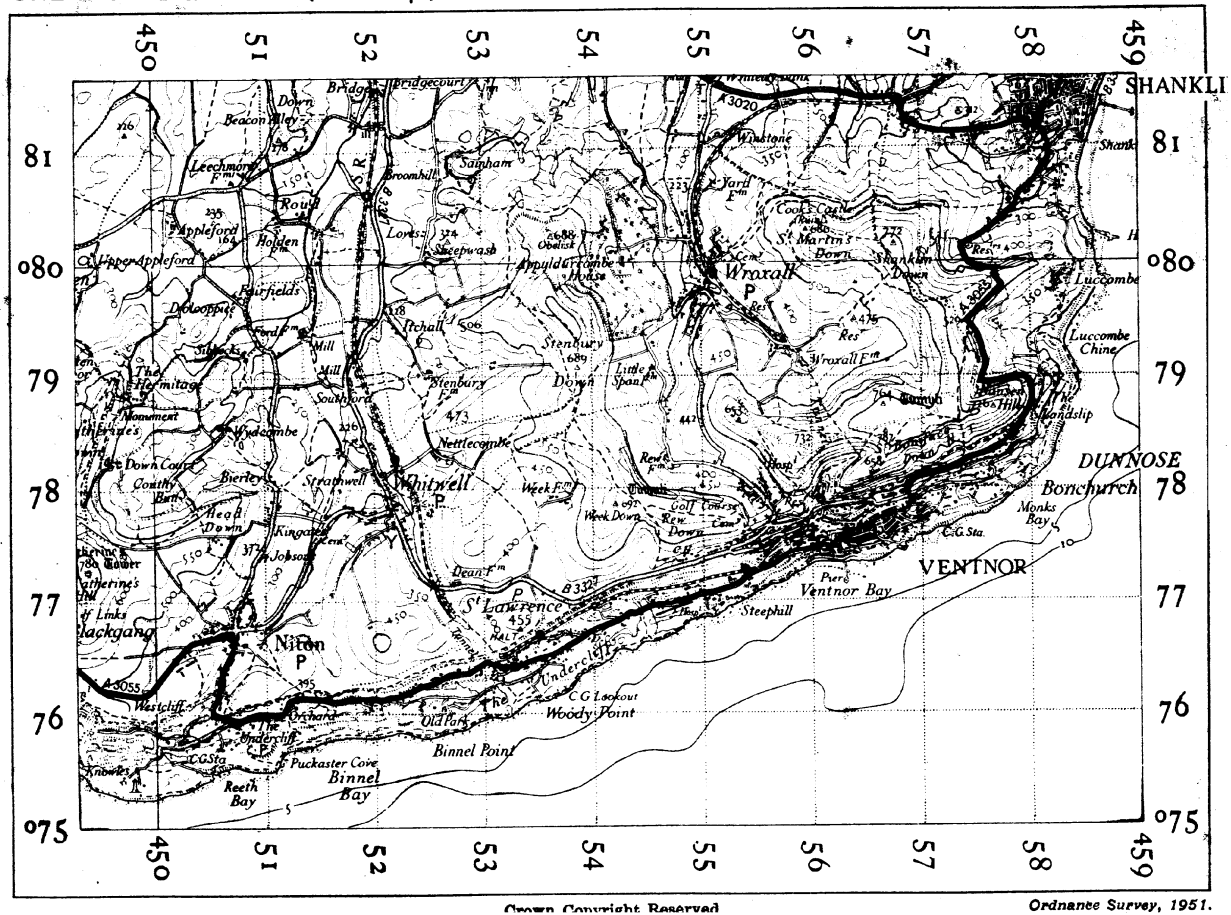
Six-inch and 25-inch plans are given (facing page 8), and it will be seen that relatively few features are shown on these compared with the one-inch map. A noticeable feature is the field boundary. This is particularly well shown on the 25-inch specimen. The fields are numbered for reference, and the acreage is shown. The continuous line of dots in the south-east corner of the map represents the line of a hedge. The double parallel lines denote a road or footpath (marked F.P.). The buildings are clearly shown to scale, and the symbols for trees are sufficiently large to enable clear distinction to be made between conifers and deciduous trees. This is a neat little map of a complete economic unit, a farmstead.

On the 6-inch plan, fields are shown, but in less detail than in the 25-inch plan, which serves admirably for estate plans. The 6-inch plan shows contours in red, features not included on the larger-scale map. The slopes can be traced, and sections might be drawn, say, (1) from the quarry in the S.E. of the map to the lych gate in the west; (2) along a north-south line drawn along the centre of the map. Note the stippling to indicate park land, and the symbols for the trees.

5. CONVENTIONAL SIGNS

To aid legibility in map reading, it is necessary to employ distinctive symbols for various features, and to make use of different types of lettering for different purposes. These symbols and methods of lettering are set out in what is known as the *Characteristic Sheet of the Conventional Signs and Writing,* used for the various types of Ordnance maps. They differ somewhat for each type. For example, more symbols for certain purposes are used for the one-inch map than for the six-inch plan, and symbols for the same feature are not always the same on both series.

In connection with conventional signs use is made of colours and symbols. On many maps streams are blue, woods are green, and roads are red. Such colours at once give a clue to the features depicted. Methods for showing relief deal mainly with physical features, especially land forms. There are numerous symbols to indicate man-made features, such as roads, railways, canals, bridges, aqueducts, churches, windmills, water-pumps, beacons, lighthouses, houses, and other buildings.


SHANKLI
DUNNOSE
Bonchurch
VENTNOR
Ventnor Bay
Monks Bay
Wroxall
St Martin's Down
Luccombe
Luccombe Chine
Shanklin Down
Wroxall Fm
Landslip
Whitwell
Nettlecombe
Stenbury
Stenbury Down
Little Span
Week Down
Week Fm
Golf Course
Dean Fm
St Lawrence
Undercliff
Steephall
Niton
Westcliff
Orchard
Old Fm
Woody Point
C G Lookout
Binnel Point
Binnel Bay
Puckaster Cove
Reeth Bay
Blackgang
Leeches Fm
Broomhills
Sainham
Roud
Appleford
Upper Appleford
Holden Fm
Fairfields
Dolloppes
Ford Fm
Mill
Itchall
Lores
Steepwash
Appuldurcombe
Obelisk
Bridge
Bridgecourt
Beacon Alley
Down
Winstone
Yard Fm
Cook's Castle
Res
Bonchurch Down
Monument
Wydecombe
Down Court
Country Park
Bierley
Strathwell
Head Down
Kingcott
Johnson
Hospital
Pier
C.G Sta.
Tower
Links
Pier
Tunnel
Rew Down
Rew Fm
Res
Res
Res

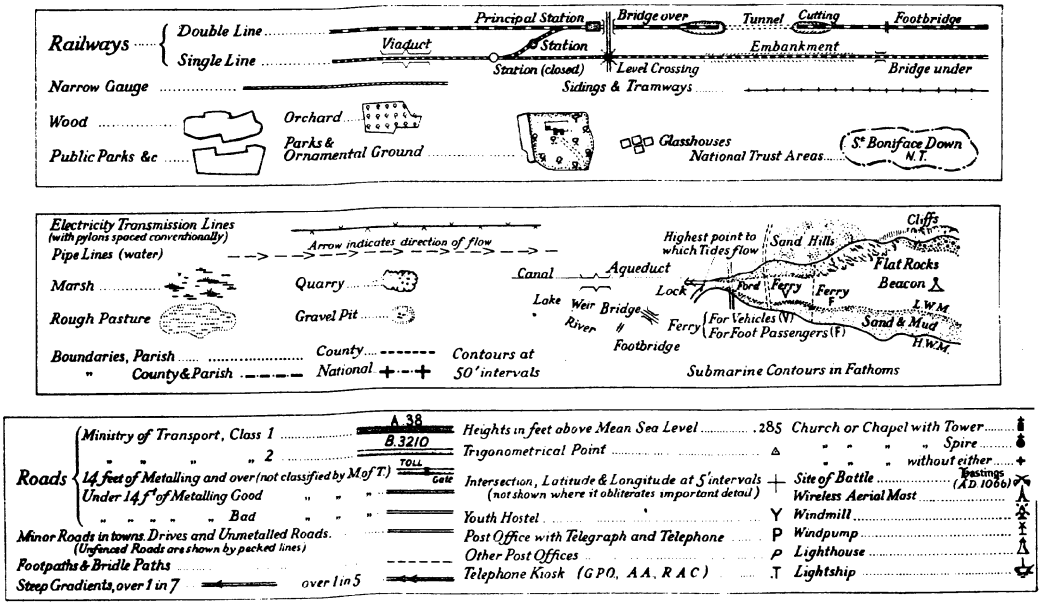


FIG. 10. SYMBOLS USED IN THE NEW POPULAR (SIXTH) EDITION OF THE ONE-INCH ORDNANCE SURVEY MAPS.

Such conventional signs are shown on what is termed a characteristic sheet, and some are given on the margin of the official maps. (See Figs. 10 to 12.) They are best learnt by constant practice in interpretation and application. Popular and easily understood descriptions of the British Ordnance Survey maps are contained in official publications issued by the Ordnance Survey Department. These should be obtained, as well as Index Sheets of the maps on the scale which it is intended to use. From these Index Sheets it is possible to identify the map of any particular region and to gauge its extent.

The one-inch map is widely used for ordinary purposes, and is generally selected for examination questions dealing with map interpretation and analysis. Therefore it will be advisable to procure the characteristic sheet for the New (Sixth) Popular Edition (1946) one-inch map of Great Britain, and to study it carefully. Until you are familiar with the various symbols, always have it by your side when studying the map, and from time to time refer to it for revision. Excerpts from the characteristic sheet are printed in the margin of Ordnance maps, but they do not show all symbols, nor do they emphasise the significance of various kinds of lettering.

A new Ordnance Survey map, known as the $2\frac{1}{2}$ inch map, uses a scale of 1 : 25,000. It is ideal for regional survey and for study of the countryside. Contours are brown and are broken in built-up areas. They are for 25, 50, 100 ft., and then with V.I. 100 ft. Trigonometrical stations are shown on churches, chimneys, or other buildings. Parish boundaries are given and they will not be confused with footpaths, as dots wider apart are used. Ministry of Transport Class A roads have continuous brown lines, Class B roads disconnected brown lines, and in both cases distinction is made between fenced and unfenced roads. There are also other roads, fenced and unfenced, not accepted by the Ministry of Transport; they are uncoloured. Multiple track and single track and narrow gauge railways are indicated by the usual symbols. Electricity transmission lines and pipe-lines (oil and water) are indicated, and on the first-named pylons are shown. Streams, lakes and ponds are depicted in a legible blue; pumps, wells, springs, and blow wells are shown. There are symbols for furze, marsh, reeds, osier beds, rough pasture, heath and moor, and watercress beds are named. Distinction is drawn between fenced and unfenced, deciduous and coniferous woods, and orchards are shown. In built-up areas the general outlines of buildings and streets are clear. The various topographical symbols, such as bridges, embankments, cuttings, are very clear.

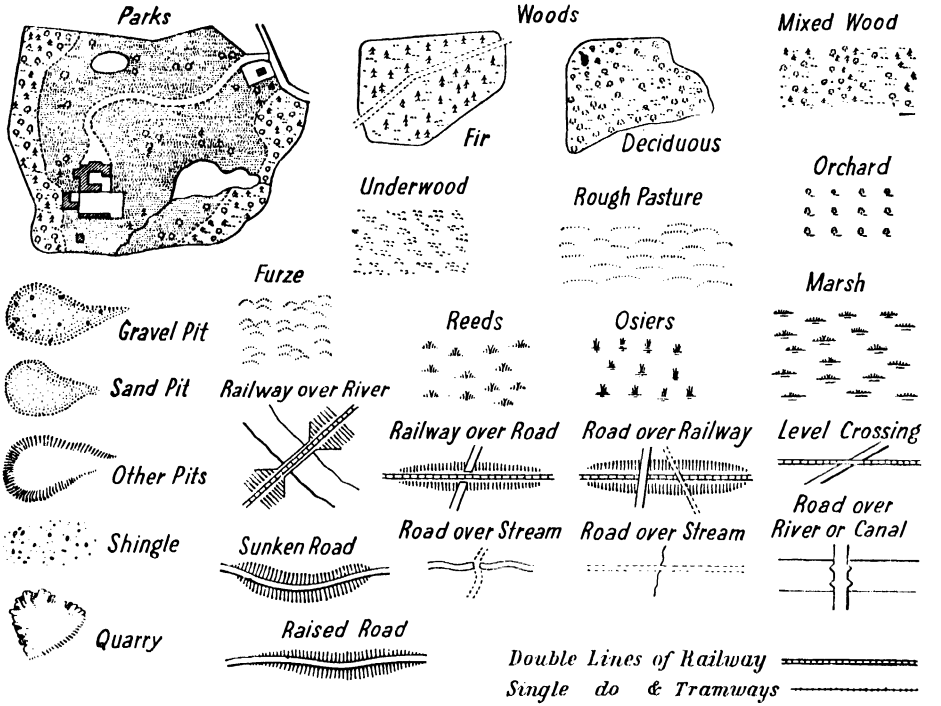


Fig. 11. Symbols Used on the 6-Inch Plan of the Ordnance Survey.

BOUNDARIES

Counties	— — — — —	Parliamentary County Divisions	Parly. Div. Bdy.
County and Civil Ph.	— · — · — ·	Poor Law Unions (Obsolescent)	Union Bdy.
Ridings	— — — — —	Parliamentary Boroughs	Parly. Boro. Bdy.
County Boroughs (England)	Co. Boro. Bdy.	Divns. of Parly. Boroughs	Div. of Parly. Boro. Bdy
County Burghs (Scotland)	Co. Burgh. Bdy.	Catchment Areas	C.A.Bdy.

Municipal Boroughs	Munl. Boro. Bdy.
Urban Districts	U.D. Bdy.
Police Burghs (Scotland)	Burgh Bdy.
Rural Districts	R.D. Bdy.
Civil Parishes	. . . . .

ALTITUDES (in Feet)

The Altitudes are above the mean level of the Sea at Liverpool or Newlyn (as stated). The Contour altitudes are written thus...200 Altitudes along roads and to Trigl. Stations obtained by Spirit Levelling, are written thus 300·, the dot showing the spot at which the altitude is taken.

Altitudes with the letters *B.M.* marked * against them, refer to marks made on Buildings, Walls, Milestones, etc.

The Latitudes are given on the margin to every 30 seconds, and the Longitudes to every minute.

Fig. 11 *continued.*

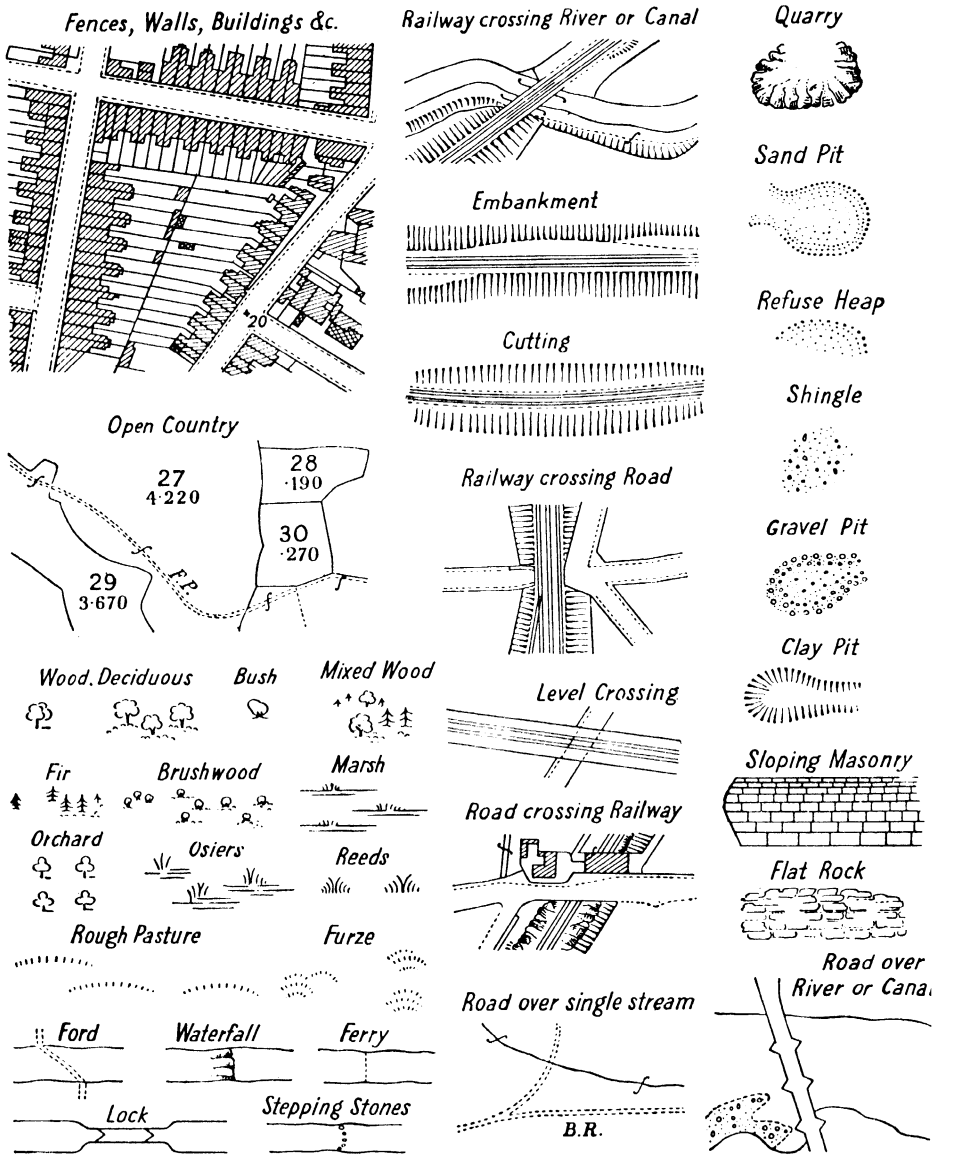


Fig. 12. Symbols Used on the $\frac{1}{2500}$ Plans of the Ordnance Survey.

AREAS

Every parcel is numbered thus 27

Its area is given underneath in Acres, thus ..... 4·370

Braces, indicating that the spaces so connected are included in the same reference number and area ..... The track in this case is excluded. ——,——, —— included.

ALTITUDES (in Feet)

The Altitudes are above the assumed mean level of the Sea at Liverpool or Newlyn (as stated). The Contour altitudes are written thus 200
Surface Levels along roads and to Trigl. Stations, obtained by Spirit levelling, are written thus 326+, the cross showing the spot at which the altitude is taken.
Altitudes with the letters **B.M.** marked against them, refer to marks made on Buildings, Walls, Milestones, etc. (Bench Marks).

CONVENTIONAL SIGNS

Electricity Pylon ..... E.P.
Telephone Call Box ..... T.C.B.
Police ——,——,—— P.C.B.
Mile Stone ..... M.S.
Pump ..... P.
Signal Post ..... S.P.
Guide Post or Board ..... G.P.
Letter Box ..... L.B.

Trigl. Station ..... ▲
Altitude at Trigl. Station ..... 507 ▲
Bench Mark ..... **B.M.** 325·9
Surface Level ..... 342 +

Boundary Stone ..... B.S.
——,—— Post ..... B.P.

Foot Bridge ..... F.B.
Foot Path ..... F.P.
Bridle Road ..... B.R.

Antiquities (Site of) .....

Arrow denotes flow of water .....

High or Low Water Mark of Ordinary Tides ..... H. or L.W.M.O.T.
——,—,—— Spring ——,—,—— ..... H. or L.W.M.S.T.

Sluice ..... Sl.
Trough ..... Tr.
Spring ..... Sp.
Well ..... W.
Mooring Ring ..... M.R.

BOUNDARIES

Counties .....
County & Civil Ph. .....
Ridings .....
County Boroughs (England) **Co. Boro. Bdy.**
County Burghs (Scotland) **Co. Burgh Bdy.**

Parliamentary County Divisions **Parly. Div. Bdy.**
Poor Law Unions (Obsolescent) **Union Bdy.**
Parliamentary Boroughs **Parly. Boro. Bdy.**
Divisions of Parly. Boroughs **Div. of Parly. Boro. Bdy.**
Municipal Boroughs **Munl. Boro. Bdy.**

Municipal Wards **Ward Bdy.**
Urban Districts **U.D. Bdy.**
Police Burghs (Scotland) **Burgh. Bdy**
Rural Districts **R.D. Bdy.**
Civil Parishes .....

Fig. 12 *continued*.

BOUNDARIES—*continued*

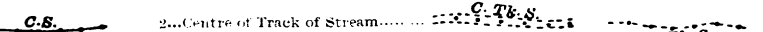
Method of showing the Boundaries in connection with the Detail.

The initials are placed where a change occurs in the nature of the Boundaries as referred to a road, wall, stream, drain, or fence, and the symbol ⊣ is used for marking the extent of the Boundary to which the initials refer.

1...Centre of Stream



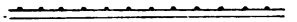
2...Centre of Track of Stream

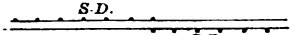


3...Centre of Road

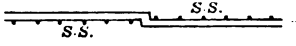


Side of Stream or Drain

4.. 

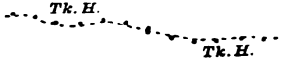
5.. 

Drain or Stream Straight, Boundary changes Sides

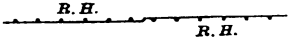
6.. 

Boundary Straight, Stream or Drain changes Sides

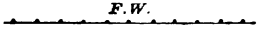
7...Track of Hedge



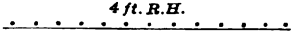
8...Root of Hedge, Face of Cop, Side of Fence

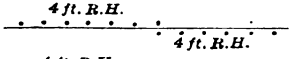


9...Face of Wall

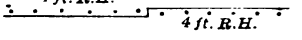


4 feet from root of Hedge or Fence, etc.

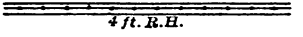
10... 

11.. 

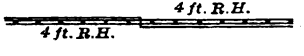
Fence Straight, Boundary changes Sides

12.. 

Boundary Straight, Fence Changes Sides

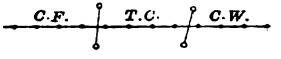
13.. 

Stream on the Boundary side of Fence

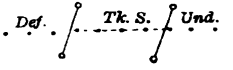
14 . 

Boundary Straight, Fence changes Sides

15...Centre of Fence, Top of Cop, Centre of Wall, etc.



16...Defaced or Undefined, Track of Stream, Drain or Fence



From 4 to 9 the dots should be in contact with the line which represents the Side of Stream or Drain, Root of Hedge, Face of Cop, Side of Fence, Face of Wall.
From 10 to 14 the dots should not be in contact with the line which represents the Hedge or Fence, etc.
No. 15—The dots should be on the continuous line representing Centre of Fence, Top of Cop, Centre of Wall, etc.

THE LAND UTILISATION MAP.—An interesting adaptation has been made of the one-inch Ordnance Survey map. Some sheets have been issued to show the cartographical results of a Land Utilisation Survey directed by Dr. Dudley Stamp, the object of the Survey, in the words of its Director, being " to make a complete record over the whole of Britain of the uses to which the land is put at the present time."

The basis of the special **Land Utilisation map** is the one-inch map (Popular Edition) on which additional information is printed in six colours. A distinctive letter symbol is used with each colour. Dark green (F) is used for forest and woodland; light green (M) for permanent grass and meadow; brown (A) for arable land; yellow (H) for heath, moorland, commons, and rough pasture; purple (G) for allotments, gardens, and orchards; red (W) for land of no agricultural value. The method is easy to follow, and the ordinary details of the map can be read quite easily, though the added colour tends to obscure the relief features. These can, however, be read. Two interesting maps are the One-Inch Sheet No. 114, Windsor, covering the region south-west of London, and Sheet No. 142, Isle of Wight, including also part of the New Forest and Portsmouth. They are examples of two contrasted areas, the one typically urban and suburban, the other largely rural.

The Land Utilisation map, as well as being of interest to contemporary geographers, should not be without historical value subsequently, in the same way as the Agricultural Surveys of Arthur Young give a picture of the agriculture of certain British counties at the end of the eighteenth century. His surveys were more generalised and were descriptions of farming methods seen during journeys rather than detailed scientific surveys of all the land.

Other interesting maps of the Ordnance Survey are Aviation maps: the quarter-inch Civil Air edition covering England and Wales (12 sheets) with special information relating to flying, and a map covering Great Britain (3 sheets) on a scale of ten miles to one inch, with flying information symbols in blue, showed conditions previous to 1939. There is also a ten miles to the inch layered map of Great Britain (3 sheets) intended for motorists and others who require maps covering a large part of the country.

The Ordnance Survey have issued maps on a scale of 1/M, notably a population map of Great Britain based on the 1931 census, maps of Roman and Anglo-Saxon Britain, a map of 17th Century England, a physical map of Great Britain. There is also a Geological Survey 1/M map showing British coalfields.

CHAPTER V

HINTS ON MAP READING

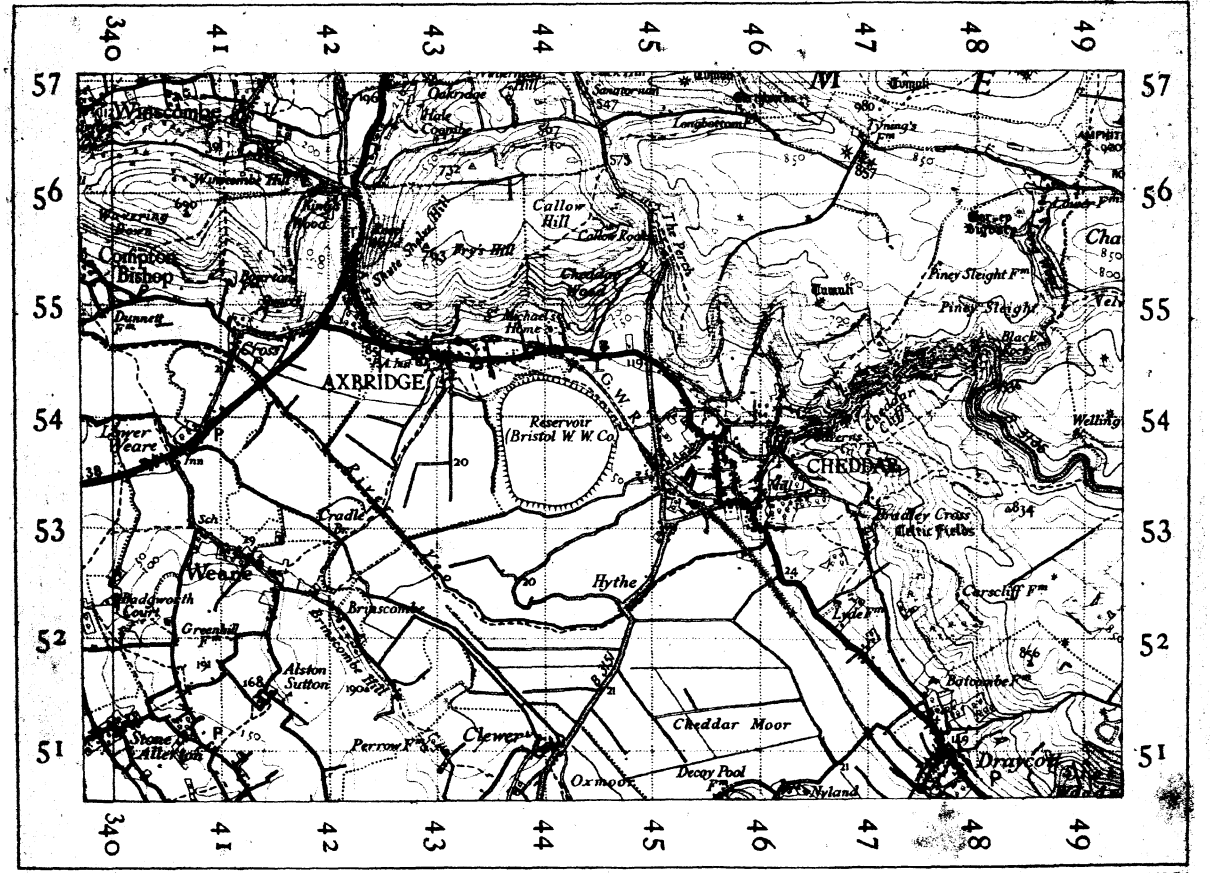
1. ESSENTIALS OF MAP READING

Ability to set a map and to identify your position are essential aspects of outdoor map reading, but some things connected with map reading can be done indoors, for instance, mastering conventional signs, and methods of showing relief. Such practice is best developed out-of-doors, but the alphabet of outdoor map reading can be learnt indoors.

To read a map requires knowledge of the methods of indicating relief, of the conventional symbols, of scales, of bearings, of the use and significance of the compass. Such things are, as it were, the alphabet and grammar of map reading, but taken singly and without proper combination and correlation, they no more constitute map reading than the Greek alphabet and grammatical rules constitute a knowledge of Greek literature. They are a means to an end, and must be used to create a mental picture of the country with which they deal. They must help us to visualise it as if we saw it from a high mountain or from an aeroplane. We must see solid and should remember that the map deals only with area.

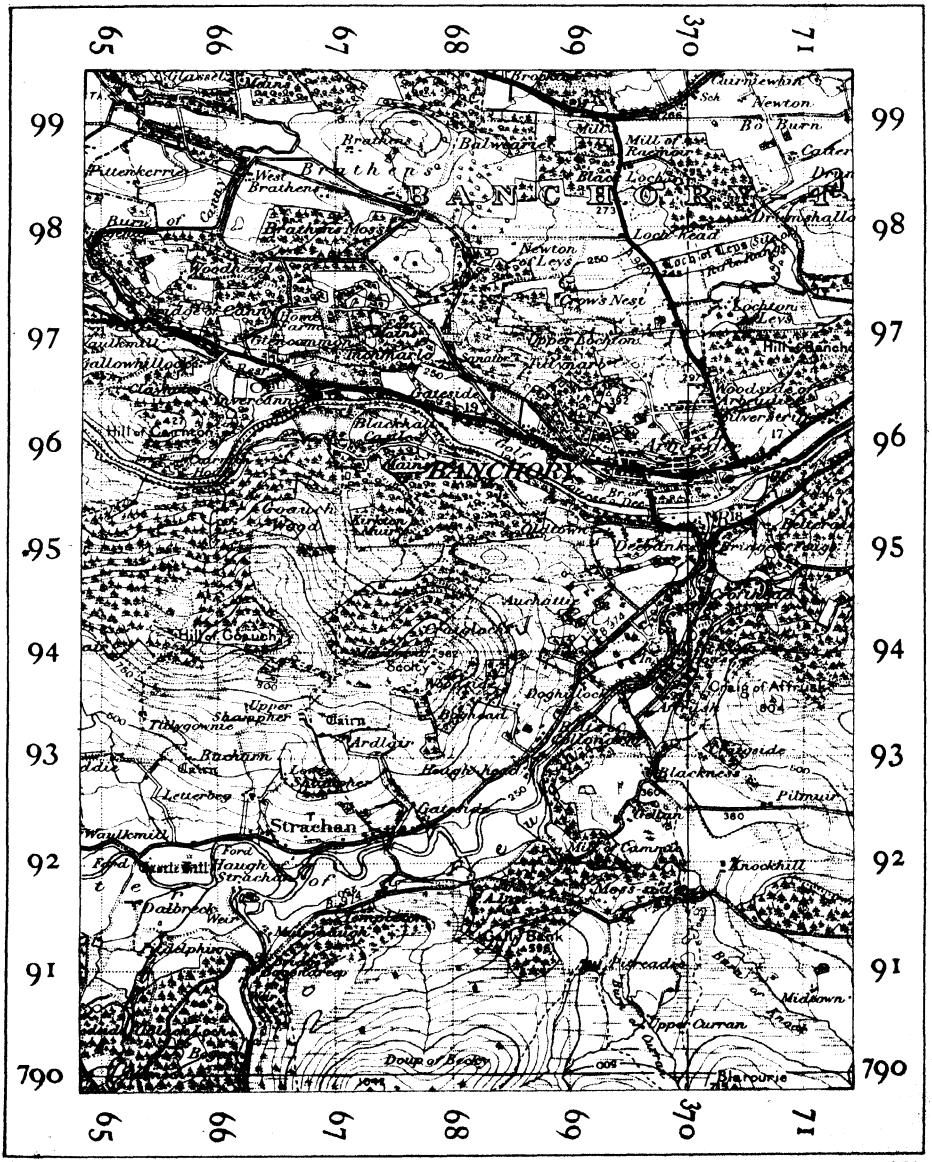
The scale of a map is one of the first things which should be considered. Try to recall on the same scale some other map of country with which you are familiar. Note on the new map a small area corresponding in size to ground known to you. This will give a standard of comparison as regards extent, and you will probably be able to estimate how long you would take in walking, cycling, or motoring from one point to another. Such ability to think in terms of distance helps to give an air of reality to your mental picture.

Practise setting the map as if actually in the field, that is, try to visualise the country in relation to what would be north, and try to visualise prominent objects in relation to your own position. This will help to give you the map-setting instinct whenever you use maps in the field. For indoor study such a plan is infinitely preferable to staring at the map, and noting the various symbols merely as symbols. Also, mentally take bearings on the imaginary position of certain objects. This will train you in estimating bearings approximately, and in realising the significance of a bearing. (See Chapter III)



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Ordnance Survey, 1951.



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2. PHYSICAL FEATURES

As regards the content of the map, very important are the physical features, particularly the mountains, hills, and streams. Relief and water features are intimately connected. Most of the valleys are valleys of erosion, and indicate the course of the principal streams. Thus, the streams afford a key to the valleys, which help us to visualise the hills. Chapter VI. deals with some aspects of the physical basis of map reading, notably in connection with streams.

It is a good plan to make from the Ordnance map a tracing of the streams and another of the contours. You can examine the streams separately, likewise the contours, and then place the stream tracing on that of the contours, so that hills, valleys, and streams can be examined together. Contours will not indicate minor features of relief, but such can often be identified by the help of spot heights or of hachures on the Ordnance map. It is not advisable to show hachures or hill-shading on tracings, which are meant to give a clue to the general character of the relief. Too much minor detail will obscure the general character.

A good exercise which will emphasise the meaning of the contours is to make a separate tracing of, say, the 100-ft. contour on a sheet of cardboard or thin two-ply wood and to cut round the contour with a fine saw. Do the same with each of the other contours, and place the pieces of cardboard or wood one on the other in their proper sequence. Thus you have a model of the country. Plasticene may be used to round off the sharpness of the contour edges, and in doing this the hill-shading or hachures of the Ordnance map will be useful. A fairly elaborate model can be made by inserting the streams in blue pencil, and by using suitable colour wash for the various features, for example, green for woodland or pasture, brown for arable land.

In some examinations where an Ordnance map is given for analysis and description, candidates are asked to suggest suitable physical or physiographic divisions. Some general knowledge of the physical geography and geology is desirable if this division is to be made scientifically and on a real geographical basis. It is not difficult to suggest divisions for a fairly large area such as the Pennines or a county like Lincolnshire, but the sheets usually given do not comprise such extensive areas. They are generally one-inch maps of the normal size of twenty-seven by eighteen inches. One such sheet would contain but a small proportion of the Pennines and possibly some of the bordering plain. A Lincolnshire sheet might represent part of the Wolds, with a little of the Marsh or Clay Vale lowland.

In attempting to formulate physical divisions, the first thing is to distinguish the higher and the lower land. Then look for river basins or portions of such, if all the river does not appear on the map. Often river basins will be suitable physical divisions, but sometimes sub-division of them is desirable, as, for instance, the highland and lowland course. On the map facing page 32, compare the valley of the Dee with that of its Feugh tributary. For the hilly or mountainous part of a map you may have a well-developed plateau or ridge with a steep slope, known as the escarpment. Note the Mendips and their escarpment on the map facing page 32. It is unsatisfactory to attempt division into physical regions without some general acquaintance with the rock formation. For instance, in the Southern Pennines physical character of the areas differs where limestone and millstone grit respectively predominate.

3. IMPORTANT TERMS CONNECTED WITH RELIEF FEATURES

It is necessary to know the meaning of certain terms connected with relief features, and from the form of the contours to be able to recognise such features.

It is not always easy to determine what is a hill and what is a mountain, and the distinction is rather arbitrary. Broadly speaking, many authorities would label as a **mountain** land whose highest point is over 3,000 ft. above the surrounding country. Land whose summit is less than 3,000 ft. above the surrounding country they would term a **hill.** The highest part of a mountain or hill is the **summit,** and the lowest part the **base,** and the limit of 3,000 ft. is reckoned between these two points. Selection of 3,000 ft. as a distinguishing mark for mountain and hill may be broadly convenient, but to apply it in every case would lead to a not very suitable classification for relief like the Pennines, because it would result in the highest summits of these uplands being classed as hills.

Certain features are common to both mountainous and hilly land, and they are identified on the map by the shape and trend of the contours. A circular or elliptical contour in the form of a small ring and with no other contours inside it represents the summit of a peak. A small triangle or dot with a number inside the ring signifies the highest point of the summit. Several concentric rings, if the height is fairly great, represent a detached mountain or hill. If the height is low, such a feature is termed a **knoll.** Examples may be found in lowlands with deposits of clay and stones derived from the moraines of glaciers

which formerly covered the country, or of sand and gravel deposited by rivers after the ice had receded, as in Holderness and parts of the Fenland. A low, elongated hill of glacial boulder clay is termed a **drumlin.** Drumlins may be seen in the south-west of the Southern Uplands of Scotland and in the Tweed Valley. They are very common in the north-east of the United States of America. Hillocks of fluvio-glacial sand and gravel are called **kames,** and the long winding ridges common in Ireland are known as **eskers.**

Contours may be of roughly elliptical shape, but covering a much larger area than in the case of a drumlin. The altitude is also greater. Such an arrangement gives a **ridge** if the length is much greater than the width, and a **plateau** where the top is wider and the surface relatively flat. Inside the highest contour of a ridge there may be small circular contours representing local minor heights somewhat above that of the ridge generally. If two such minor heights are close together, there is a depression known as a **col** between them. A col is also known as a saddle or neck. On two sides of a col there is an upward slope of the sides of the enclosing heights; on the other two sides there is a downward slope along the sides of the main ridge below the level of the col. Almost any one-inch Ordnance map of regions like the Scottish Highlands gives examples of such features. Examples of a ridge can be seen in the main line of the Lincolnshire or Yorkshire Wolds, the Chilterns or the Downs. The Cheviots and the Pennines afford examples of plateau surface, but relatively low plateaux can be found in counties with much glacial drift, as the low boulder clay plateau east of the Lincolnshire Wolds, or the plateaux of central Norfolk and Suffolk.

Any high land, ridge or plateau, separating two drainage systems or river basins is known as a **water-parting** or **watershed.** From the highest part of the ridge there is a slope in two opposite directions, just as there is a similar slope on a house-roof. During rainfall some water flows down one slope of the roof into a convenient spout, and some down the other slope. So with the watershed in mountainous or hilly country. The rain flowing down one slope makes for the nearest lower land, where it helps to erode valleys and thus to develop stream systems. Rain which flows down the other slope results in the development of another set of streams. The two stream systems are separated by the high land, and the suitability of the term water-parting is obvious.

A model of most high land would show many depressions which cut into it. These depressions are **valleys,** generally of streams, and a plateau very much cut up like this is termed a **dissected plateau.** Good examples may be

found in many parts of the Scottish Highlands. Because of their uniform height and great development of valley features, the Scottish Highlands as a whole are often referred to as a dissected plateau. It will generally be seen that contours representing valleys fit into one another like a number of dishes of varying size. One end of the valley, that nearer the source, is defined by contours, but the other end, where the stream leaves the higher land for the plain is not so defined, and may be compared with a dish from which an end is broken.

In identifying the valleys on a contoured map, it may be helpful to begin with the lower end and work upwards to the stream's headwaters. Because streams are generally coloured blue on large-scale maps, it is comparatively easy to identify valleys, but it is not so easy to form a mental picture of the way in which they dissect the high land.

The lowest part of a valley, namely, where the streams actually flow, is called the **watercourse**, and the watercourses obviously form a key to the surface drainage of any region. We say surface drainage, because sometimes, as in a limestone country, there is a well-developed system of underground drainage, but this is not shown on the map. A surface stream may disappear underground and then reappear at some other point. Only its surface course is shown on the map by the conventional blue line. The underground course may be gauged by a dotted line or may be left blank. At first it is difficult to visualise the features of a district where such drainage occurs. Some elementary knowledge of the rock structure is desirable, as well as acquaintance with the properties of limestone. Hence the importance of elementary acquaintance with a geological map of the region with which the contoured map deals. Underground drainage is discussed in Chapter VII. Examples of such drainage may be found in the Central and Southern Pennines, and in the Cheddar district of Somerset.

The **brow** or **crest** is the actual edge of a hill-top or of the upper part of a slope. The **crest-line** or **ridge-line** is the line representing the highest level along the highest part of the ridge. A **spur** is a projection from high into lower ground; it is part of the higher ground, just as a buttress is part of a wall. A **re-entrant**, as it were, is an incision into the side of higher ground, and roughly has the same level as the surrounding low land. The upper part of a valley in a hilly region is a re-entrant. If you are trying to read a contoured map where no streams are shown, at first sight it is sometimes difficult to determine which are spurs and which are re-entrants, but if you work outwards from the highest contour, the nature of the features will soon be grasped. The sides of a valley, hill, ridge, or

mountain are known as the **flanks**. If the slope is very steep, it is termed a scarp or **escarpment,** from the French word *escarpé* = steep. Examples of all these terms can be found on the maps of the Lake District facing page 64.

Slopes are known as **convex** when the contours are closer together near the lower ground, and as **concave** when the space between contours is greatest towards the lower ground. If contours are evenly spaced, the slope is said to be **uniform.** The character of the slope is important in determining the visibility or otherwise of one point from another.

4. METHODS TO DETERMINE VISIBILITY

To determine whether a given point on the ground is visible from another point involves consideration of changes of slope between the points. Often this problem can be solved by examination of the contours, but it is possible that between two contours there may be a minor feature, some trees, or a high building which will interfere with visibility under actual conditions, despite calculations which seem to suggest perfect visibility.

Visibility can be investigated by examination of the slopes which are deduced from the contours, by comparison of gradients or by drawing sections from the contoured map.

By Contours.—If the contours are examined, it can be seen whether the slopes are convex or concave. When the slopes are predominantly convex, as in Fig. 16, the points are not mutually visible. If the slopes are concave, as in Fig. 15, the points are mutually visible but for unexpected intervention of some minor feature or obstruction which cannot be deduced from the contours. Proficiency in this method of determining visibility will sometimes follow practice in section-drawing.

By Comparison of Gradients.—The method of determining visibility by comparison of gradients is best explained by reference to practical cases exemplified by Fig. 13. Careful examination of the contoured map is needful to identify the lower and higher of the two points with which we are concerned. It is also necessary to know the distance between the two points, which can be determined by using the scale of the map. Some crest intervening between the two points must be utilised.

Example. Consider Fig. 13. Is A visible from B?

Let C be a crest along the 400 ft. contour, and 600 yd. (*i.e.* 1800 ft.) from B and 650 yd. (*i.e.* 1950 ft.) from A. Therefore A is 1250 yd. (*i.e.* 3750 ft.) from B.

(1) Gradient from A to C $= \frac{100}{1950} = \frac{1}{19{\cdot}5}$

(*i.e.* $\frac{\text{V.I.}}{\text{H.E.}}$, because **gradient** is ratio of Vertical Interval to Horizontal Equivalent).

Note. The Vertical Interval is the difference between two successive contours; the Horizontal Equivalent is the horizontal distance between two successive contours (Chapter XVII.).

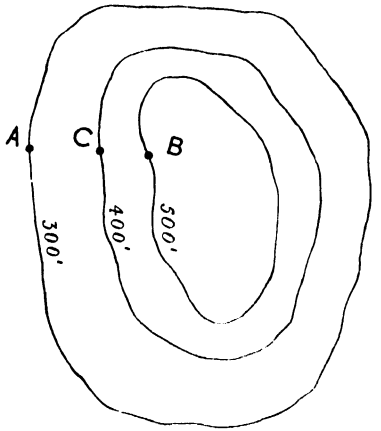


Fig. 13. To Determine Visibility by Comparing Gradients.

Gradient from A to B $= \frac{200}{3750} = \frac{1}{18{\cdot}75}$.

As gradient from A, the lowest point, to the crest C is *less*[1] *steep* than from A to B, the points A and B are mutually visible.

(2) Gradient from C to B $= \frac{100}{1800} = \frac{1}{18}$.

Gradient from A to C $= \frac{100}{1950} = \frac{1}{19{\cdot}5}$.

As gradient from A, the lowest point, to C is *less steep*[1] than from C to the highest point B, the points A and B are mutually visible.

From the above we can deduce the following rules:—

(1) Find gradient x from the lower point to an intervening crest, and gradient y from the lower to the higher point. If x is steeper than y the points are mutually invisible, but if x is less steep than y they are mutually visible.

(2) Find gradient x from lower point to an intervening crest, and gradient y from this crest to the higher point. If x is steeper, the points are mutually invisible; if x is not the steeper, they are mutually visible.

By Drawing a Section.—To draw a section is a reliable method unless some unknown under-feature intervenes. A section is a profile drawing of the elevation given by cutting vertically downward through a model of the features.

[1] If this gradient had been the steeper, in each case the points would have been mutually invisible.

Example. Consider Fig. 14. The line AB represents the line of the desired section. It cuts the contours at certain points, a, b, c, d, etc. Take a piece of paper, here represented by the squared-paper, and place below the contoured map, marking on this paper a vertical scale XY, 100 ft., 200 ft., etc., to correspond with the contoured intervals. Drop perpendiculars from the points a, b, c, etc., in AB to meet the horizontal lines marked 100 ft., 200 ft., etc., on the vertical scale XY, giving positions a', b', c', which, when joined, will represent the required profile.

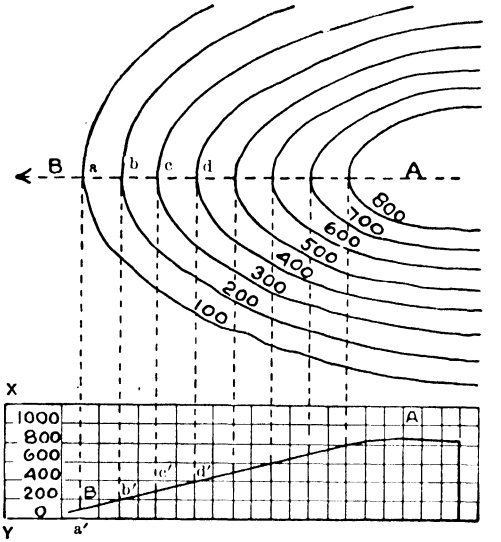


Fig. 14. Uniform Slope of Spur.

Such profiles are approximate, and in some sense guesswork, as minor features may occur between contours and thus are not represented on the contoured sketch. However, spot heights may sometimes give greater accuracy to a profile if they are wisely used as guides when they occur on the top of a ridge, etc.

A profile of a road can be made by drawing on a piece of squared or lined paper profiles of the various stretches of the road, moving the paper for each stretch as though you were drawing separate sections.

5. COMMUNICATIONS AND SETTLEMENTS

Tracings should be made of the communications and of the settlements. These tracings can be studied together and in conjunction with the physical tracings. The roads and railways are influenced by the rivers and the relief. They avoid equally the low marshy tracts near the streams and the more rugged relief. See the map facing page 32, which represents part of the marshy Yeo valley and the Mendip Hills. The meaning of nodality must be understood. A village or town site is said to be nodal when several routes converge upon it like

strings tied together in a knot. The word "nodal" comes from the Latin *nodus*, a knot. Banchory (see map facing page 32) and Cheddar (see map facing page 32) are examples of nodality. Cross-roads constitute a nodal point and sometimes mark a village site. Gap towns, that is towns near a gap or pass through a hill range, are nodal, and so are bridge towns near where a bridge crosses a river. Leeds and Guildford are gap towns near routes across the Pennines and North Downs respectively. Newcastle and Oxford are bridge towns.

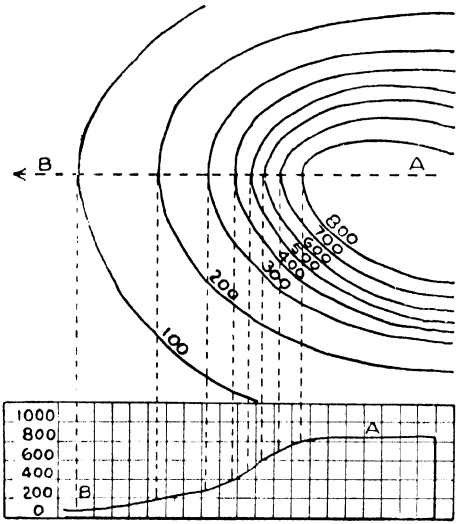


Fig. 15. Concave Slope of Spur.

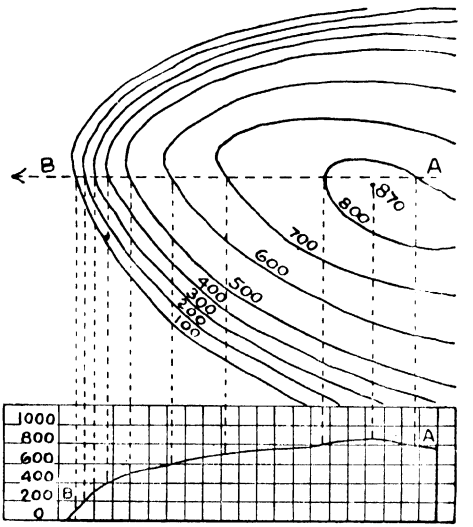


Fig. 16. Convex Slope of Spur.

Adequate water supply has always been an important consideration in selecting a village site. Villages were often established around springs which gush out at the junction of chalk or limestone and the underlying clay on the escarpments of the Wolds, Downs, and Cotswolds. Where streams and springs are scarce the possibility of sinking wells governed the choice of village sites, as on the Lincolnshire Marsh and in the London Basin, where there is abundance of underground water which saturates the chalk like a sponge and is prevented from sinking deeper by the impervious clay which underlies the porous chalk.

CHAPTER VI

PHYSICAL BASIS OF MAP READING

1. SIGNIFICANCE OF RELIEF

The relief of a region is a key to its physical geography, and this helps to explain much of the human geography. Contours show the position of mountains and hills, their general outline, and their height. This higher land helps us to understand the direction and character of the drainage. Frequently it helps us to understand the climate, especially rainfall and temperature conditions. After inspecting even a small-scale relief map of Northern England showing the Pennines, we realise that the longest rivers flow from the eastern slopes towards the North Sea, and that the westward-flowing streams are much shorter. We also notice that the western slopes are exposed to the rain-bearing winds from the Atlantic, and thus can understand why the Lancashire side receives more rain than the West Riding of Yorkshire. We can also understand why Lancashire is less exposed to cold east winds.

Inspection of larger-scale maps shows well-defined valleys of streams which join the Ouse, and of other rivers rising in the Pennines. The contours suggest many interesting features, such as plateaux or relatively flat uplands, escarpments, depressions across the Pennines where the Aire and Tyne Gaps give relatively easy east-to-west routes.

However, it is not sufficient merely to be able to read the contours and to say what features they represent. In order to interpret the map with reasonable fullness and to understand the character of the various features, it is necessary to know something about the elements of physical geography.

2. AGENTS OF EARTH SCULPTURE

We sometimes speak of " earth sculpture," meaning the processes by which various features have received their present form. Just as a sculptor's tools, his chisel and mallet, have been used to shape a statue, so various agents have assisted in shaping features on the earth's surface. Two of the most important

of such agents are water and ice, water mainly in the form of streams, and ice as glaciers or ice-caps.

Streams have carved valleys in highland and lowland alike. The material removed in carving the valleys has been transported elsewhere and deposited to make flood-plains,[1] alluvial fans,[1] and deltas.[2] A stream performs (1) destructive work, known as **erosion,** (2) constructive work, known as **deposition.** It acts as a transporting agent, and its load of material resulting from erosion does a certain amount of destructive work known as **corrasion.**

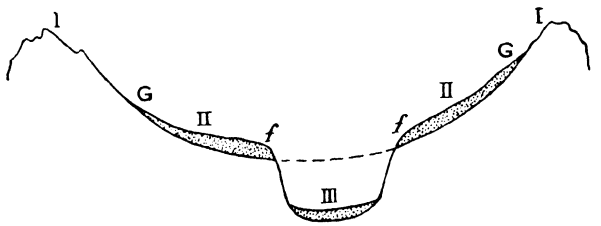


Fig. 17. VALLEY FEATURES TO ILLUSTRATE THE WORK OF ICE.

Generalised cross-section of valley which has been subject to geologically recent ice-action. The depth of the valley is exaggerated to emphasise the features.

I, I. Mountain heights which the glacier did not reach; it did not fill the valley higher than G, G. Hence the highest peaks show the irregular outline of ordinary erosion contrasted with rounded forms due to glaciation.

II, II, are ledges or "shoulders" (the French call them *épaulements*) once covered with ice, which has left behind it débris to form the soil supporting the grass on the Alpine Pastures (*alpes*). Often such ledges contain a tributary (hanging) valley which joins the main valley at *f*, *f*, where falls occur, useful sources of hydro-electric power.

III is the floor of the valley, where the main stream flows; it is U-shaped and was probably excavated by the ice below the dotted line which may be taken as the approximate level of the pre-glacial valley.

3. THE WORK OF ICE.

Glaciers are limited to intensely cold regions, and it is obvious that rivers, being much more numerous, have played a greater part in shaping physical features. However, in Britain and elsewhere, when the climate was much colder, there were glaciers and ice-sheets which have left their mark on the surface. To-day glaciers are confined to high mountains outside the British Isles; ice-caps occur not far from the polar circle. Knowledge of their work enables us to understand certain features in countries like the British Isles and Northern Germany, which were once covered with ice.

Like rivers, glaciers perform a threefold work: (1) destruction, (2) transport, (3) construction. They move very slowly, but in their passage break off rock particles, which they carry with them and leave behind when changed climatic

[1] See page 44. [2] See page 45.

conditions or arrival below the snowline causes the ice to melt. A glacier with the aid of tools, *i.e.* rock fragments, rather than by itself rubbing the ice, widens and deepens existing valleys, makes hollows which may become lake basins, and, with its transported débris, mantles pre-existing surface features.

Such mantling is irregular, and in the hollows thus formed lakes are frequently found, as in the Masurian region of the North German Plain and in Finland.

The constructive work of a glacier includes the formation of (1) low ranges of hills of boulders and clay known as **moraines,** like the Baltic Heights in Prussia and the Cromer Ridge in North-East Norfolk, (2) low, elongated hills of boulder clay, generally regarded also as moraines, known as **drumlins.** Rivers of the Ice Age have further left deposits of sand and gravel, forming ridges known as **kames,** or, where long and narrow, as **eskers.** Examples of both eskers and drumlins are found in Eastern Cheshire and along the estuarine area around Wigtown Bay in the Galloway region of South-Western Scotland. Eskers occur on the Carlisle Plain in Cumberland, and, with drumlins, may be found in other once-glaciated regions of Britain. Glacial soils, especially those derived from boulder clay, often form fertile land in Holderness, Lincolnshire, and East Anglia.

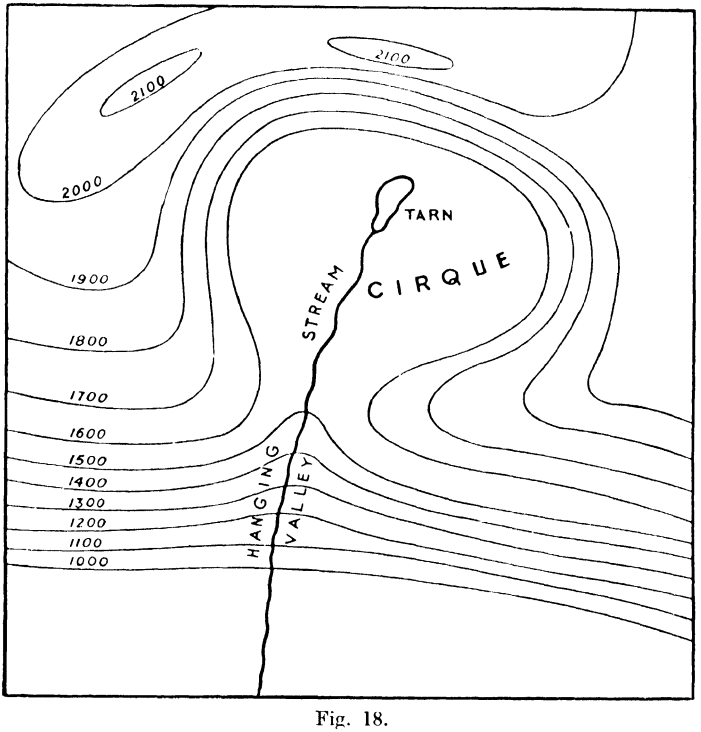


Fig. 18.

Glacial débris has modified valleys and turned streams from their original course, as in the case of the Derwent, which formerly flowed into the North Sea, but by glacial débris was diverted in an opposite direction to become a tributary of the Yorkshire Ouse. It rises not more than two or three miles from the North Sea, but now has a westward course of about one hundred miles to the Ouse.

Ice-sheets formerly covered the British Isles as far south as the Thames Valley, and many parts of the country show the effects of former glaciation. Resulting features, in addition to eskers and drumlins, include many lake basins in the Lake District and Scotland, which, if not actually formed by glacial action, were largely modified by the destructive and constructive action of ice. Existing hollows were deepened by the ice, and valleys were dammed by transported débris. The boulder clay cliffs of Holderness are of glacial origin, this clay being a glacial deposit which owes its name to the large number of transported rock fragments known as boulders.

4. THE WORK OF STREAMS

A large-scale contoured map of most British regions would show more features due to streams than to ice. Streams in their upper courses as a rule are swift and do much destructive work, wearing relatively deep and narrow valleys, the waste material of which they carry along with them. Such narrow, steep-sided valleys are common in the Lake District, the Scottish Highlands, and North Wales.

When streams reach land of gentler slope their velocity is checked and much of the material carried is deposited. The débris carried and deposited by a stream is known as **alluvium,** and many plains have been formed by such deposition when a river is in flood. The Vale of York is largely the alluvial **flood-plain** of the Ouse and its tributaries, the Vale of Pickering that of the Derwent. Coarser débris, such as gravel, is sometimes deposited in the shape of a fan, so that the resulting feature is known as an **alluvial fan.** Examples are found in the valleys of small streams flowing from the Lincolnshire Wolds into the Bain, itself a tributary of the Witham. Villages are situated on these easily drained fans. Alluvial fans, used as village sites, occur at the mouth of glens drained by rapid streams flowing from hills which, like the Ochils in Central Scotland, overlook a plain.

The Fenland owes much of its surface to deposits from rivers, though considerable areas along the Wash have been reclaimed from the sea. In map

analysis many interesting features connected with flood-plains will be noticed. In flowing over a plain, a river's velocity is relatively slow and it cannot carve a very deep valley, deposition generally being more active than erosion. Thus sediment is built up on the bed, and as the bed is raised there is more and more tendency to flood. A very slight obstacle can turn aside the river, which twists and bends to form the curves known as "**meanders,**" from the name of a river in Asia Minor where this feature is very noticeable. Such rivers often change their course, part of the old meander being left in the shape of a crescent to form what is known as an ox-bow lake or mort lake.

Meandering rivers shown on British maps sometimes receive small straight water courses which are artificial drainage channels, *e.g.* in connection with the Feugh tributary of the Dee shown on the map facing page 32. These features emphasise the indecisive character of the natural drainage, and are attempts by man to make the riverside lands fit for meadows. In Britain, villages are rarely near the river, but are situated on higher land some distance away. (See map of the Yeo valley and Cheddar region facing page 32.) Rivers in their lower plain course swing from side to side of the valley, and raise the level of their bed so that they sometimes overflow and even change their course. To avoid flooding, such rivers are embanked, as in the Fenland and along the Trent.

When a river enters a lake or the sea, its velocity is checked and its load is deposited, forming a **delta,** a triangular piece of land so named from the shape of "delta," the Greek capital D. Several of the English lakes have deltas and on their deltaic plains the drainage is very indecisive. See map facing page 64 for examples in connection with the lakes Grasmere, Rydal Water, and Windermere. Deltas are not common round the English coast, because waves and tidal currents there are very active and prevent deposition of sediment. English rivers, as a rule, end in **estuaries** or mouths where tides scour out the estuary at ebb, *e.g.* the Mersey. In the Tyne and Clyde estuaries the scour is less active, heavy dredging being necessary. In most estuaries there has been partial marine submergence of valleys originally cut by rivers.

From the contoured map it is easy to study various forms connected with streams. In the upper part of the course, comprising what is sometimes known as the valley tract, corrasion is more active than deposition. The river thus deepens its channel and a valley develops. If the river were the only erosive force the valley sides would be practically vertical. The river cuts vertically downward, but at the same time weathering agents, such as rain, extremes of

temperature, especially frost, wear away the valley sides, widening the valley most at the top of the slopes, so that a V-shaped cross-section results.

The character of the V depends upon the hardness of the rocks and upon the climate, especially the amount of rainfall and the length of time during which the river has worked. If the rocks are hard, the V will be relatively deep and narrow, as in Lake District valleys; if they are soft, as in the clay vales of Eastern England, the V will be wide and relatively shallow. Heavy rainfall tends to give a gentle slope to the valley sides, because there is much lateral[1] corrasion, though hard rocks counteract such corrasion and produce a steeper slope than if the rocks were soft. Examples are seen in the steep-sided valleys of the Lake District, where the hard rocks to some extent minimise the effect of the heavy rainfall. Rocks, like limestone, which are termed permeable because they quickly absorb rain water, allow relatively little lateral erosion, their valleys being narrow and steep-sided, as in the limestone regions of the Central and Southern Pennines. The cross-section of a "youthful" stream valley has a very sharply defined V shape.

Probably no arrangements of contours better repay study than the various forms of re-entrant. If the re-entrant is wide the valley is probably mature, indicating that the river's work has continued for a long period; if the re-entrant is narrow, it usually signifies a youthful valley. Here it is advisable to consider the terms **mature** and **youthful** in relation to what is known as the **cycle of erosion.** Several years ago, a famous American geographer, Professor W. M. Davis, suggested the term cycle of erosion in connection with the life history of streams. Three ideas are involved: **structure, process, stage. Structure** concerns the kind of rocks subjected to such destructive process, and it is also necessary to consider the relative resistance to erosion of various kinds of rock. **Process** refers to the type of destructive process and its power, *e.g.* running water, ice. **Stage** brings in the time element, the relative time during which the destructive agents have operated, and defines the stage of destruction reached: youthful or early, mature, senile or late. Sometimes a stage intermediate between early and mature is recognised; it is known as adolescent.

In the **youthful** stage, gradients are steep; vertical, *i.e.* downward, erosion is very active and works rapidly. The longitudinal profile, *i.e.* the section curve along the length of the valley, is steep, and is irregular if hard rocks alternate with soft. Waterfalls and rapids are frequent and sometimes there are lake

[1] *I.e.* wearing away of the sides.

basins which receive and discharge rivers. Cross-sections of youthful valleys are sharply V-shaped. They are relatively deep and narrow, and their sides are very steep. Tributaries are not numerous, and those which develop show most of the youthful characteristics. Such streams are usually short and their gradients are very steep. They are very narrow and have little or no flood-plain, a characteristic also associated with the main stream. A feature of youthful valleys is the development of interlocking spurs. That is, on the map there is a series of bends, especially where harder rocks have offered resistance to the cutting of a straight valley. One bank will be concave, the other convex. The convex bank, representing a spur or projection, fits as it were, into the concave bend.

The **adolescent** stage is chiefly characterised by a wearing away of many of the interlocking spurs, because lateral erosion becomes more active as the gradient of the main stream is lessened by the tendency of deposition to exceed corrasion.

In the **mature** stage the development of a valley becomes more pronounced and a flood-plain is built up when deposition considerably exceeds corrasion. Meanders are common. While the middle course begins to show these mature characteristics, the upper course may still show all the signs of youth. The longitudinal profile becomes more **graded**, that is, inequalities of slope tend to disappear. The volume increases, so does the load of débris worn away further up-stream, and this load by its grinding action helps to deepen the channel. Lateral erosion is also increased and assists the development of meanders. The cross-section of mature streams shows a wider V, but where meanders have developed, there may be remains of the bases of interlocking spurs, which in time disappear. Tributaries are more numerous and their valleys develop towards maturity. Their own tributaries show youthful characteristics in the upper courses.

In the **senile** or late stage, the relief becomes very slight and the longitudinal curve is almost flat, grading (or base level) being practically attained. Falls and rapids have disappeared, and lakes are silted up. Steep slopes are nowhere seen, and spurs have been worn away as the valley has widened. The shallow open valley shows hardly any trace of the V-shaped cross-section. Tributary valleys are almost as fully developed as that of the main stream, and tributaries are very numerous, forming a veritable network of watercourses.

Sometimes, after senility has been reached, renewed activity or **rejuvenation** of streams occurs, due perhaps to some earth movement which steepens the gradient,

or to increased rainfall. The destructive work of the streams recommences, and they begin to deepen their channels again. Their previous flood-plain is now above the level of possible flooding and remains as a **river terrace.** Examples of river terraces are found west of the Lea valley in the Thames basin, in the lower Clyde valley, and on the Thames flood-plain just below Oxford. What are known as **incised meanders** are sometimes cut downwards after rejuvenation. They are meanders with steep sides, such as those of the Wye, of the Wear near Durham, of the Dee near Llangollen.

5. STREAM SYSTEMS AND THEIR DEVELOPMENT

So far, we have considered valley development in relation to individual streams, but it is also desirable to consider the evolution of a drainage system in

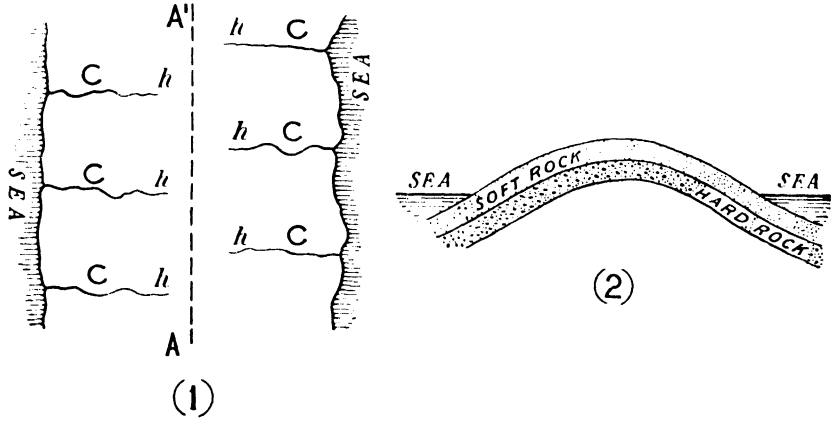


Fig. 19. Initial Stage in Stream Development (Consequent Streams).
AA', axis of uplift (anticline or upfold) whose cross-section from sea to sea is somewhat as shown in (2); *h*, stream headwaters (springs); C, consequent streams.

which several streams are concerned. It is usual to consider the case of rocks raised in the form of an arch or dome, such, for instance, as the Pennines. One slope may be taken as typical. Rain which falls runs down it, and streams develop in the direction of such slope. They are roughly parallel, and because their direction is in consequence of the slope, they are known as **consequent** streams. When their valleys are cut, rain water will begin to flow into them from the sides, and tributaries at right angles to the parent stream will develop. In the

theoretical example it is generally assumed that there are alternate bands of harder and softer rock parallel to the watershed, and that the tributaries develop along the softer bands. The harder beds will be cut out where the valleys of the consequent streams form, but elsewhere they will remain as ridges along the valleys of the subsequent streams. Their steep slopes form escarpments. Such escarpments often undergo considerable modification, but the processes involved are beyond the scope of this book.

The headwaters of consequent and subsequent streams tend to work backwards into their respective watersheds. One of the consequents may be more rapid or may have greater volume than its fellows, and in its valley erosion will be more active. The valley will thus become deeper, and its tributaries will have a steeper gradient. Their headwaters will be active agents of erosion and eventually will cut back into the valley of their neighbour, which they will divert into their own valley. This is known as **stream capture** or **beheading**. (See Figs. 22 and 23.)

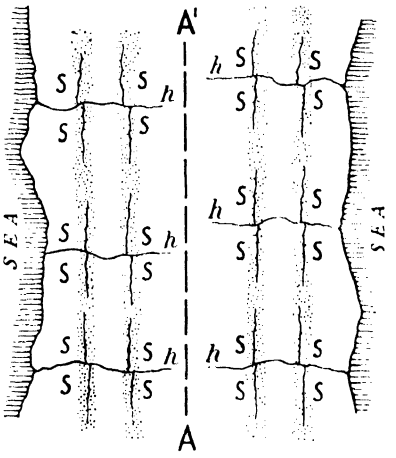


Fig. 20. Further Stage in Stream Development (Consequent and Subsequent Streams).

As in Fig. 19, *s*, *s* being subsequent streams developed on bands of softer rock (shaded).

The lower part of the beheaded river, fed by the tributaries below the point where the capture occurred, will continue as a separate but smaller stream. Part of the valley of the captured stream will remain dry, but in another part from which it was diverted, a small stream, known as an **obsequent**, may develop and flow in a direction opposite to that of the consequent.

In time the strongest of the consequents may capture the headwaters of all the others. Tributaries concerned in the capture may eventually become larger than their original parent stream. Streams flowing in valleys apparently too large for them are termed **misfits**, as some of the Cotswold streams of the upper Thames basin. A dry valley cut through an escarpment is called a **wind-gap**; several wind-gaps through the Chilterns and Downs escarpments serve as route-ways.

A practical application of the ideal case outlined above may be seen in the rivers flowing from the Pennines through Northumberland into the North Sea. The Pennines form a watershed with a considerable eastward slope, along which flow the Tyne, Blyth, Wansbeck, and Coquet. The Tyne has two branches, the North and South Tyne. The South Tyne and the Coquet rise near the main watershed. The Wansbeck and Blyth rise considerably further east. The North Tyne has several right-bank tributaries which rise on the main watershed and are in a straight line with the Blyth and Wansbeck. At the outset, Tyne, Blyth, Wansbeck, and Coquet were probably consequent rivers flowing from the Pennines into the North Sea. The Tyne was the most powerful, and the North Tyne seems to have cut backward and beheaded both the Blyth and Wansbeck. Eventually it will probably capture the Coquet. (See Fig. 24.)

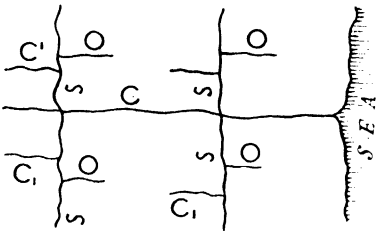


Fig. 21. Later Stage in Stream Development (Consequent, Subsequent, and Obsequent Streams).

This is only one stream system whose earlier history is shown in Figs. 19 and 20: C = consequent (C' secondary or minor consequent developed after the subsequent); S = subsequent; O = obsequent.

The term **antecedent drainage** is sometimes applied to certain river systems in South-Eastern England. Originally the rocks here were raised in the form of an arch which chalk covered throughout. Consequent streams developed on each slope of the arch, and they, with their tributaries, removed the chalk from the top of the arch, but continued in their original directions. In the lower part of the arch, except in the river valleys, the chalk resisted erosion more than did the softer rocks, and remains as two ridges, the North and South Downs, through which valleys are cut. They have been cut downward and are the much-deepened original valleys which were formed before the present relief took shape; hence the term antecedent drainage. Between the Downs is relatively low land known as the Weald, in the centre of which

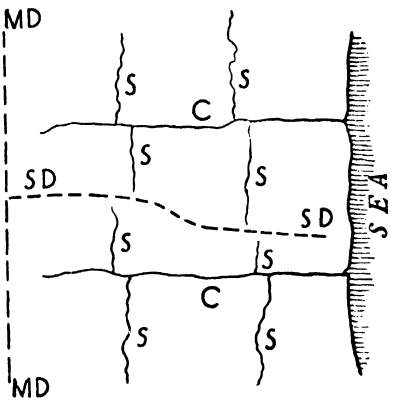


Fig. 22. Stages in Stream Capture—Before Capture.

C = consequent; S = subsequent; MD = main divide; SD = secondary divide.

is a low ridge of sandstone, from which streams proceed north and south towards and through the Downs.

The theory associating a single cycle of erosion with the Weald is now discredited. "The region has passed through one cycle of denudation, and is in an advanced stage of the second."[1] The consequent streams due to the initial uplift of the Wealden dome had reduced the area to a peneplain (almost a plain) when further uplift rejuvenated the drainage. Since then the streams have been

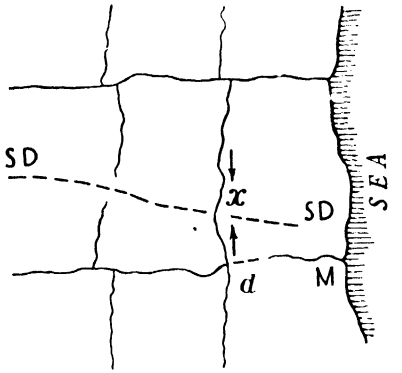


Fig. 23. Stages in Stream Capture — After Capture.

At x the secondary divide is breached by subsequents working backwards in directions shown by arrows, the stronger and more northern stream diverting the other and beheading the main stream M.
SD = secondary divide; d = windgap.

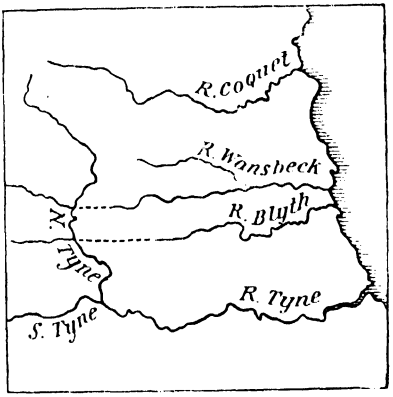


Fig. 24. The Northumberland Rivers to Illustrate Capture.

The probable former upper courses of the Wansbeck and Blyth are shown by dotted lines. The N. Tyne possibly captured first the Blyth and next the Wansbeck.

deepening and widening their valleys and little denudation now takes place except in the High Weald.

The term **superimposed drainage** is exemplified by the rivers of the English Lake District. Much of this district consists of old hard rocks which were once covered by newer softer rocks in the form of a dome. Streams flowed in all directions down the slopes of the dome, radiating from its centre like the spokes of a wheel, whence the term **radial drainage.** Erosion removed the newer beds except for a ring around the older rocks. The streams continued to cut their valleys downward and have kept the directions originally due to the dome-shaped

[1] C. C. Fagg and G. E. Hutchings in *Great Britain.*

softer rocks. They cut down to the harder beds across which they flow to-day. These harder beds did not determine their direction, which seems in no way related to the present structure. It is imposed upon, rather than due to, the older and harder beds which to-day constitute the core of the Lake District. (See page 62.) Superimposed drainage is not confined to the Lake District; much of the drainage of Northern Britain must have been developed on chalk or newer rock surface.

High land may be studied in conjunction with streams, since the latter carve the valleys which dissect mountainous regions like the Highlands and Southern Uplands of Scotland or the flanks of the Pennines. In dissection of high land the main factors are the velocity and erosive power of streams and the degree to which different rocks respond to such mechanical erosion. There is another aspect of erosion, the chemical, mainly due to the way in which the calcium carbonate (lime) of limestone rocks or chalk responds to the solvent action of rain-water containing carbon dioxide derived from the atmosphere. Owing to its numerous fissures, small and large, limestone is a porous rock, and rain readily sinks into it, so that there is little surface flow off in the form of streams. The solvent action of water accumulating along cracks and joints forms underground channels which have their own streams, a surface stream sometimes disappearing and reappearing some distance away. This is known as **intermittent drainage.** Underground channels may widen into caves, whose roofs sometimes fall in, forming narrow, steep-sided gorges like that of Cheddar in the Mendips.

6. COASTAL FORMS

Those Ordnance maps which include a stretch of coast require special interpretation. It is necessary to consider the various types of coast, as well as certain broad aspects of their physical geography.

Two important types of coasts may be broadly classed as **drowned** (or sunken) and **raised,** or, as it is sometimes put, coasts of **submergence** and coasts of **emergence.**

Drowned Coasts.—In drowned coasts, which are essentially sunken land surfaces invaded by the sea, the former character of the land forms is evident. If the drowned country was mountainous, there is much alternation of peninsulas and islands, straits and openings, the latter often being fine harbours. In Britain there are two types of drowned mountain coast, the **fjord** coast of Western Scotland and the **ria** coast of South-Western Ireland and South-Western England.

In very mountainous regions the drowned valleys form long, narrow, steep-sided lochs or **fjords,** but sometimes a valley has not been drowned and contains a lake. In Argyllshire, just north of Oban, Loch Etive is a fjord, but a little further inland, south of Ben Cruachan, a granite mountain, is an unsubmerged valley containing Loch Awe, a lake, which very little sinking would transform into a fjord. The valleys are evidently river valleys which had been modified by ice before the lower reaches were invaded by the sea. The straight, steep walls of the valley sides and the U-shaped cross-section suggest the work of ice. The frequent occurrence of tributaries at right-angles to the main valleys and sharp right-angled turns or zig-zags in the latter, point to fracture lines in the earth's crust, along which the streams etched the original valleys before these were deepened and widened by the ice. The tributaries are frequently hanging valleys at a higher level than the main valley, and when a stream occupies the undrowned upper reach, a waterfall tumbles into the fjord.

The land around the fjords, which is known as their **hinterland,** is rugged and unproductive, so that, though the fjords form very good harbours, no large ports have developed, the only settlements being small fishing villages, which, like Oban, occasionally develop into holiday resorts.

Ria coasts have not so rugged a hinterland as have the fjords, and there is no evidence of the work of ice. In South-West Ireland the rocks by some earth movement were crumpled up to form ridges (upfolds) with intervening down-folds, the whole similar to the wrinkles in the skin of a dried orange. The down-folds in which river valleys had developed were drowned in their lower reaches and became **rias,** the upfolds persisted as peninsulas. The rias have few tributary valleys, but the streams flowing into the ria heads tend to silt up the latter, though the scour of the tides to some extent negatives such silting. Except where a port has developed for reasons other than purely commercial, as on Plymouth Sound in Devon, where the port has risen round a naval dockyard, ria coasts are almost as barren of human settlement as are the fjords.

A **drowned lowland** coast occurs in South-East Suffolk and Essex. The relief is very slight, and the weak gradient has resulted in shallow stream valleys. Parts of some have been submerged, forming estuaries, which, but for the tidal scour, would soon be blocked by silt. If deposition by marine currents parallel with the coast is more than the streams and tides can remove, a spit will form across the estuary, as at Landguard Point. Eventually a lagoon must result, as

in the case of the Norfolk Broads, the river flowing into the lagoon, which it will gradually silt up. The river may be diverted as in the case of the Alde.

Many interesting features are shown on an Ordnance map of the Orwell-Stour estuaries. The permanent channel is discernible between mud banks which are covered at high, and exposed at low, tide. Ill-defined streams or creeks drain into estuaries, and protective embankments point to periodical flooding. The maps show a number of low islands, such as Horsey Island and Canvey Island, which have been reclaimed and embanked. Much of the coast, however, is in a state of periodical flux. At high tide there is an expanse of shallow water which recedes at low tide and leaves a surface of sand and mud, which, where deposition by marine currents is not counteracted by tidal scour, will eventually develop into permanent low islands intersected by creeks.

Raised Coasts.—A good example of a coast of emergence is the eastern shore of the U.S.A. in North and South Carolina and Georgia. Before uplift, the sea bottom near the land would be made smooth by the normal process of deposition, so that the relief of the newly-emerged area was smooth, and the coastline marked by long, simple curves. Behind such new coastal belt, more varied relief and steeper slope usually marks the older land.

The Marsh of Eastern Lincolnshire is essentially a pre-glacial wave-cut shelf covered with boulder clay and more recent deposits. Before the emergence of this coast, the eastern edge of the Wolds was the shore-line, evidence of this being the occurrence of marine shells and fossils in sand and gravel along the Wold borders.

Marsh coasts which have attained some stability are parts of the marsh lands of Lincolnshire and Northern Norfolk. They were once sea bottom, but, since elevation, have been built up of deposits brought by streams from higher inland areas and by marine currents from elsewhere along the coast where denudation by the waves has been active. Such coasts are regular in outline, unfretted by any indentation except the mouths of small streams which have flowed across the marsh from the Lincolnshire Wolds or the West Norfolk Heights.

Cliffs and Beaches.—Interesting coastal features are cliffs, which may be (1) the fractured end of chalk hills, as Beachy Head or the Flamborough cliffs; (2) the edges of hard rock, as the cliffs bordering Exmoor or the granite cliffs of Cornwall; (3) the edge of boulder clay remnants of the Ice Age, as the cliffs of Holderness. To understand cliff recession is to realise how beaches are formed, and how coastal débris is transported by currents to form sandbanks, as in the

Wash, or spits like Spurn Point, both largely derived from waste denuded from the Holderness shore. Waves weaken and wash away the lower part of a cliff which they can reach at high tide. The overhanging upper part eventually falls and is dashed about by the waves, furnishing material for subsequent attack on the lower part of the cliff, when the destructive process is repeated. The eroded débris is ground into small pebbles, shingle, and then sand, the heavier portions being spread out to form a beach, the lighter being transported elsewhere.

7. SITES OF HUMAN SETTLEMENT

In map analysis it is important to study the sites of human settlement and to explain how far geographical factors have operated. Site values have changed at different periods, but we can say broadly that in the early days of settlement the main essentials of a good site related to defence, water-supply, nearness to food supplies or means of raising them. Later, another important site-value was facility for exchanging surplus products with neighbours, and thus the route settlement, the bridge-town or confluence settlement, developed. Still later, at the advent of the industrial age, power was an all-important consideration, so that the industrial town and the mining village grew up near the coalfield.

Types of villages to be noted in addition to the mining village, are the suburban village, the agricultural village, coast villages. There may be straggling route villages stretching along a main road, as in the Fens, where there are many small-holdings, more compact villages grouped around cross-roads or situated in the blind end of tributary stream valleys, as in the Central or South Wolds of Lincolnshire. They are typical valley villages where the original controls of settlement were fertile alluvial soil, adequate water supply, and a dry site for the dwellings.

It is well to note some of the general influences of relief and topography upon human settlement and to apply or adapt them to particular cases when various maps are studied. Probably they will apply best when the British one-inch Ordnance maps are analysed.

Note the different controls exerted by valleys and hill-slopes or hill-tops. In the Lake District, along the Pennines, or the Chalk Downs, there is very little settlement on the higher land. The valleys of the Lake District, whether they carry rivers or lakes, account for practically all the settlement, sparse as it is. The extended lines of small villages or hamlets fringe the valleys where deposits of workable soil are relatively narrow and are often bordered by the steep wall of the valley sides. Hence, the villages extend in a string rather than a group.

so that as much land as possible can be assigned to each farm. Sometimes, when conditions are particularly unfavourable, only isolated farms are found, and they are largely based on sheep farming. Such conditions afford striking contrast with the relatively dense agricultural settlement of the fertile Eden Valley.

Around the lakes, larger villages and small townships have a grouped rather than a string-like arrangement of habitations. There is often a deltaic flat at the head of a lake or between two lakes, and these lowlands are more favourable to farming than are the steep-sided valleys. But many of the lakeside settlements cater for tourists during the summer, and their hotels or boarding-houses naturally group round some central focus such as a railway station. Briefly, we may say that the control in the Lake District is mainly relief control, though the heavy rainfall and bleak climate are also unfavourable to settlement on the uplands.

There are plenty of springs, and there is a sufficiency of surface water in the Lake District, but in parts of the Pennines, notably around Ingleborough and north of the Aire Gap in Yorkshire, and in South Derbyshire, the limestone structure introduces an additional negative control, namely lack of surface water. Practically all the permanent water courses are along the valley floors, and in these valleys, known as "dales," are found the human settlements of small villages or single farmsteads, with perhaps a small market town at the entrance to the dale. The upland is mostly heather-covered moor or rough grassland, at best only useful as poor sheep pasture, and frequently not good enough for that. Some parts of the Pennines are composed of impervious rock, notably millstone grit, as in North Derbyshire, and here spongy peat bogs, known as "mosses," are unfavourable to settlement or economic development.

Reference has been made to the importance of lines of villages at the base of the limestone and chalk scarps of South-Eastern England. Maps showing parish boundaries in these regions emphasise some important aspects of soil and relief control. The villages are generally found on the lower slope of the scarp, just above where a permeable rock like chalk or greensand rests on the impermeable clay. This is a zone favourable to springs. The parish boundaries often run from the village in one direction up the hill, giving sheep pasture, and in the opposite direction from the scarp on to the bordering clay vale, which supplies pasture suited to dairying. The shape of such parishes is a long, narrow rectangle. The ploughed land is generally around the village, on soil like the upper greensand of the lower scarp slope, or in the higher part of the clay vale, the lower portions of which may be dotted with single dairy farms. Examples of such parishes are

found on the Downs of South-Eastern England, Wiltshire, and Dorsetshire, and the limestone heights of Kesteven in Lincolnshire.

As a contrast to the agricultural valleys of England with their sparse farming population, take the densely-peopled mining valleys of South Wales. These steep, narrow valleys enable coal to be mined in open seams and easily transported to the coast because of a suitable gradient along the valley. But the steepness and narrowness of the valleys is unfavourable to healthy village sites. Towns and villages are crowded on the slopes, which frequently must be "climbed" by streets, so that houses rise tier above tier. There is lack of gardens, and the upkeep of roads, gas and water mains is heavy, all adding to the costly and drab living-conditions of the miners.

In addition to noting the controls of village sites, it is well to study the conventional signs used for individual villages. Thus, reference to hall, manor, farm, marsh, quarry, watermill, windmill, smithy will afford some clue to local activities. So will types of woods and orchards, and the class of road.

If possible, Ordnance maps for the districts referred to in this chapter should be consulted.

In connection with the subject-matter of this chapter, more advanced students should, if possible, refer to *Great Britain: Regional Essays*, edited by Professor A. G. Ogilvie. This gives examples of river capture in connection with (1) the Irvine and other streams in central Scotland; (2) the Ericht valley of the Tay basin; (3) the rivers of the Vale of York; (4) the Don valley near Sheffield; (5) the Steeping and Withern Eau in the South Wolds of Lincolnshire; (6) rivers such as the Teign in South-Western England; (7) the Windrush valley of the upper Thames system; (8) the lower Severn and upper Thames systems. Where this book and some of the relevant Ordnance maps are available, it is possible to follow the explanations intelligently and to apply these as particular examples of the generalised theory dealt with in this chapter. In some instances, notably in connection with the Severn and Thames, there is considerable difference of opinion amongst competent authorities.

Reference to the index of *Great Britain* will give many other examples relative to physical geography.

Students may with advantage consult the chapters on streams, coasts, etc., in books such as Lake's *Physical Geography* or Laborde's translation of De Martonne's *Smaller Physical Geography*.

H. Peake's *The English Village* is worth consulting for types of village settlement. See also Carter's *Landforms and Life*.

CHAPTER VII

STUDY OF SELECTED ORDNANCE MAPS

1. GENERAL HINTS

In a previous chapter (Chapter V.) we have suggested that the best way to study an Ordnance map and all its detail is to classify some of the more important features by means of separate tracings of such matters as (1) contours; (2) streams, canals, and lakes; (3) roads and railways; (4) village and town sites in relation to the habitations. The most profitable and really the only educational way of studying Ordnance maps is to use them in conjunction with practical work on some district known to you. It can be your home district or some region to which you have access during holiday. By practical work is meant fairly detailed examination of the region with a view to systematic geographical description. Such a description might deal with the physical features and soils in relation to human activity and settlement.

In this examination try to apply the physical geography you have learned concerning earth sculpture, particularly in connection with the work of streams (Art. 4, Chapter VI.). If you have sufficient topographical knowledge of the district to visualise it roughly from the map, a preparatory exercise is to examine the map in all its bearings by means of your tracings. The contours will suggest the land forms, and from these you can try to identify broad physical regions, such as a chalk or limestone plateau, a river valley, or the complete stream basin, an alluvial plain, or perhaps a lowland marsh covered with glacial drift. It is well to make rough notes under various headings, *e.g.* "physical features," "suggested physical regions." Later these can be revised or amplified as your practical study of the country proceeds.

Failing a complete personal survey, the next best thing is access to photographs of typical views. Gradually you will be able to expand your tracings and to build up a set of specialised maps, *e.g.* (1) of the physical features analysed to show physical regions; (2) of communications in conjunction with contours and general physical features; (3) of the habitations and distribution of population in relation to water supply, fertile soil, mineral deposits, etc.

2. PRACTICE IN INTERPRETING CONTOURS AND CONVENTIONAL SIGNS

Previous to detailed study of Ordnance Survey sheets it will be helpful to undertake preliminary exercises based on the portions of Ordnance maps included in this book. Such exercises done during re-reading of Chapters V. and VI. will furnish examples of important terms connected with relief features, streams, etc., and will serve as a useful introduction to exercises given on pages 225-27, which deal with Ordnance maps suggested for detailed examination.

Take a piece of tracing paper about the size of a page of this book, and on it draw a frame corresponding with that of the map studied. Superimpose on the map, and, guided by the contours, write in the appropriate positions the names of various features. The following plan is recommended.

Pick out the highest contour and examine the others in relation to it. This will enable you to identify forms such as a plateau, ridge, hill, peak, or knoll, brief descriptions of which are given on pages 34, 35. Next consider the slope, close contours indicating a steep slope and more widely spaced ones a gentler slope. On the tracing paper use appropriate adjectives to describe the features noted. Thus, you may identify a *ridge*, long, narrow (or broad), steep-sided (or with gentle slope); a *plateau*, broad (or narrow), relatively flat (or undulating), steep-sided or otherwise, much (or little) dissected by streams. In connection with peaks you will probably recognise the sign for a trigonometrical station. When dealing with ridges, plateaux, etc., note features associated with them, such as the brow or crest, crest-line or ridge-line, spur, re-entrant, col or saddle, cirque or corrie, escarpment.

So far you have considered the higher land. Now study the *valleys* and *plains*, with their drainage features. In a mountainous region with many close contours and sometimes in a region of uniform relief it is not easy at first sight to pick out the valleys. Read the hints on page 36. It may be desirable to use a fresh sheet of tracing paper for the valleys and streams. Trace the streams and other water features with pencil. Then mark and describe the valleys. Suitable adjectives may be used for the valleys to denote their geological age or character, *e.g.* young, adolescent, mature, senile (see page 47); torrential, narrow and deep (or gorge-like), hanging, stepped, broad, shallow, and flat. Broad, flat valleys frequently have an alluvial flood-plain, and it will be possible to identify many features associated with such plains, *e.g.* meanders, ox-bow lakes, embanked streams, straight artificial water-courses and drainage channels, marshes, deltaic

flats where a stream enters a lake, though the tides around the British Isles are not favourable to the development of coastal deltas.

Draw cross-sections and longitudinal profiles of valleys. (See page 39.) Such profiles, as well as those of roads, assist the formation of a three dimension mental picture of the region. Steep-sided cross-sections of uniform width near the floor and top of the valley indicate former glaciation, and breaks or steps in the longitudinal profile suggest rapids or waterfalls. Trace the approximate limits of stream basins and the general direction of the water-parting separating them.

Next study the *habitations*. On a separate piece of tracing paper mark the site of towns, villages, and single dispersed habitations such as farms on chalk or limestone uplands. This will assist the formation of a mental picture of the distribution of population. It should be examined in relation to the contours and streams, and a little practice will show how these have influenced the choice of settlement sites. (See pages 55, 56.) Note how *communications* link up settlements, and carefully distinguish between the various types of road, which may explain, or are a consequence of, the distribution of population. Where the physical features are unfavourable to settlement it is unusual to find first-class roads, but where population has concentrated, as in mining or fertile agricultural regions, construction of routeways has been necessary.

The foregoing methods, which are intended to help the identification of features on the map, should be applied to all the maps included in this book, and to other Ordnance maps, particularly the one-inch series. Such practice may be termed the alphabet of map-reading, and can be followed by more constructive composition describing the country represented by the map. Begin with a simple examination somewhat as follows, using the Cheddar map (opposite page 32).

Preliminary Inspection.—Note (1) closeness of contours on the top and right-hand side of the map, identifying ridge, plateau, escarpment, spur, re-entrant, gorge, dry valley, cliff, caverns, and the highest triangulation stations or spot heights for comparison with the low-lying river valley; (2) absence of contours in most of the valley, its drainage features, distinguishing between natural and artificial water-courses, road and railway bridges over water-courses; (3) contours in bottom left-hand corner of map and difficulty of obtaining from them any indication of relief features.

It is now possible to divide the area represented by the map into three well-defined physical regions indicated by (1), (2), (3), in the preceding paragraph, namely scarped upland, alluvial flood-plain, and undulating lowland. In each of these divisions identify the habitations, means of communication, and other aspects of human geography, especially possible methods of land utilisation, noting references to " moor," " wood," " rough pasture," etc. In examining the railway, note the occurrence of cuttings, embankments, and tunnels.

DESCRIPTION.—Refer to pages 69-71, which give notes on the Cheddar map.

Take each of the physical regions noted in the preliminary inspection, and, assuming that the top of the map is north, locate them. Give the direction of the upland, and especially of its escarpment, noting minor features which cause a break in the continuity of the latter. The preliminary inspection will have prepared you for this, and use should be made of suitable adjectives. The upland, which is part of the Mendips, is essentially a steep-sided, smooth-topped plateau, to some extent cut up by valleys, which are dry. This absence of surface water, and the fact that the map definitely refers to caverns, suggests limestone structure. Consider the distribution of habitations, noting how villages cluster at the foot of the escarpment where conditions favour spring formation, and contrast with the bare uplands with their few scattered farms. Connect the main roads with the valleys and the minor roads with the plateau. Steep-sided and winding will define the valley carrying the route of which the gorge is a part.

Describe the valley of the Yeo as an alluvial flood-plain, and note the character of the winding river and the artificial drainage channels. Refer to necessity for road and railway bridges, embankments, etc. The railway can be described with reference to both the Yeo valley, the scarp border and the upland. The almost entire absence of habitations in the actual river valley should be stressed.

3. THE ENGLISH LAKE DISTRICT

The large one-inch Tourist Edition sheet of the Ordnance map of the Lake District is recommended for study. It depicts a definite natural region, and is large enough for parts of it to form the basis of several exercises given on pages 225-6. The relief is very graphically shown. Interesting portions of Popular Edition sheets of this district will be found facing page 64.

The main interest in the English Lake District centres round the relief and the system of drainage. The relief furnishes examples of many different physical

features, and from the one-inch Ordnance map it is possible to obtain much varied practice in the interpretation of contours. The drainage is of the type known as superimposed drainage. (See Chapter VI.)

Superimposed drainage is apparently independent of the present rock structure. Originally the courses of the rivers were determined by some uplift of the surface and would be related to the rock structure as it then was. But in course of time the streams cut their valleys down into the older rocks, much of the surface of the younger rocks being worn away by erosion. However, the original direction of the valleys was maintained, though the rocks originally determining this direction have disappeared.

In the Lake District the older rocks which form the central part of the region are surrounded by newer rocks, which once covered the whole region and formed a kind of dome. The centre of the dome was somewhere near what is now the peak known as Helvellyn, and streams flowed from the top of the dome in all directions like the spokes of a wheel. The newer rocks have been worn away by erosion, exposing the older rocks which had been folded in a direction roughly from south-west to north-east. This line of folds eastward from Scafell to-day serves as a short watershed, but the arrangement of the valleys is definitely radial. Drainage, as from Windermere and Coniston Water, flows south into Morecambe Bay; from Wast Water, Bassenthwaite, and other lakes, south-west and west into the Irish Sea; from Ullswater and smaller lakes eastward or north-eastward into the Eden.

In many of the valleys are long, ribbon-shaped lakes fed by the upper courses of streams and drained by the lower courses in the directions noted above. The upper parts of the valleys are generally cut down into the older rocks, and in such parts there is apparently little relation between the rock structure and the direction of the valleys. The lower courses of the streams are on the newer rocks which formed the lower part of the original dome, and their connection with the original slope of the dome is apparent.

On the maps facing page 64 it is easy to trace the valleys by means of contours, and the valleys help to define features of the higher land. From the closeness of the contours it is evident that the valleys are usually steep-sided, and this is particularly noticeable along the sides of most of the lakes. The valleys cut deeply into the remains of the dome, and thus the drainage may be termed incised. It seems to cut up the surface into blocks of plateaux, from which rise wild peaks, such as Helvellyn, Skiddaw, Scafell. The wildest

scenery is where the older volcanic rocks predominate, especially round Wast Water to the west of the dome. In the south, hard rocks known as grits and shales occur, and the contours there show smoother outlines in the district of the low fells, contrasting with the high fells round Helvellyn. There is wooded and park-like scenery round Lake Windermere. On the northern part of the eastern flanks of the dome the less rugged country is mainly limestone moorland, devoted to sheep pasture. The southern part is what is known as karst, with poor limestone soil, little surface drainage, but some underground stream channels and caves.

Examination of the map shows that the English lakes are long and narrow, and often almost straight. They are partly in rock basins or hollows in the solid rock, and partly in valleys dammed by drift left by the glaciers which once covered this part of Britain. Their valley sides are very steep, often rising practically sheer from the water. Sometimes the lakes are in pairs connected by a stream, as Bassenthwaite and Derwentwater, the land between the lakes being like a delta, marshy, and avoided by roads. The stream is extending this delta and is tending to fill up the lake in the lowest part of its course.

Some of the tributary valleys are marked by contours very close together, and are obviously at a higher level than the main valley. They are known as hanging valleys, and the main valley is said to have been overdeepened. Some physical geographers say that such overdeepening occurred when glaciers covered the region, the erosive power of the ice being greater in the wider valley. Those who believe glaciers to have little erosive power think that ice in the main valley protected it from erosion by water, but that streams could develop and cut backwards on the slopes above the ice. Their valleys would be above the level of the main valley and when the glacier disappeared they would remain as hanging valleys. From these valleys, cascades drop into the main stream or into a lake. The famous Fall of Lodore is near Derwentwater. The wild region round Wast Water has many hanging valleys and waterfalls. There are many tarns or small lakes in rock basins, especially east of Thirlmere, and several of them drain into Ullswater or the Eden by means of short streams.

The highest slopes and summits are bare of vegetation. The valleys are generally marked by wooded slopes, and lakeside woods are features of the scenery. Note the closeness of the contours on the heights round Skiddaw, and how they widen out to show the Greta valley. Roads, railway, and villages are in this valley.

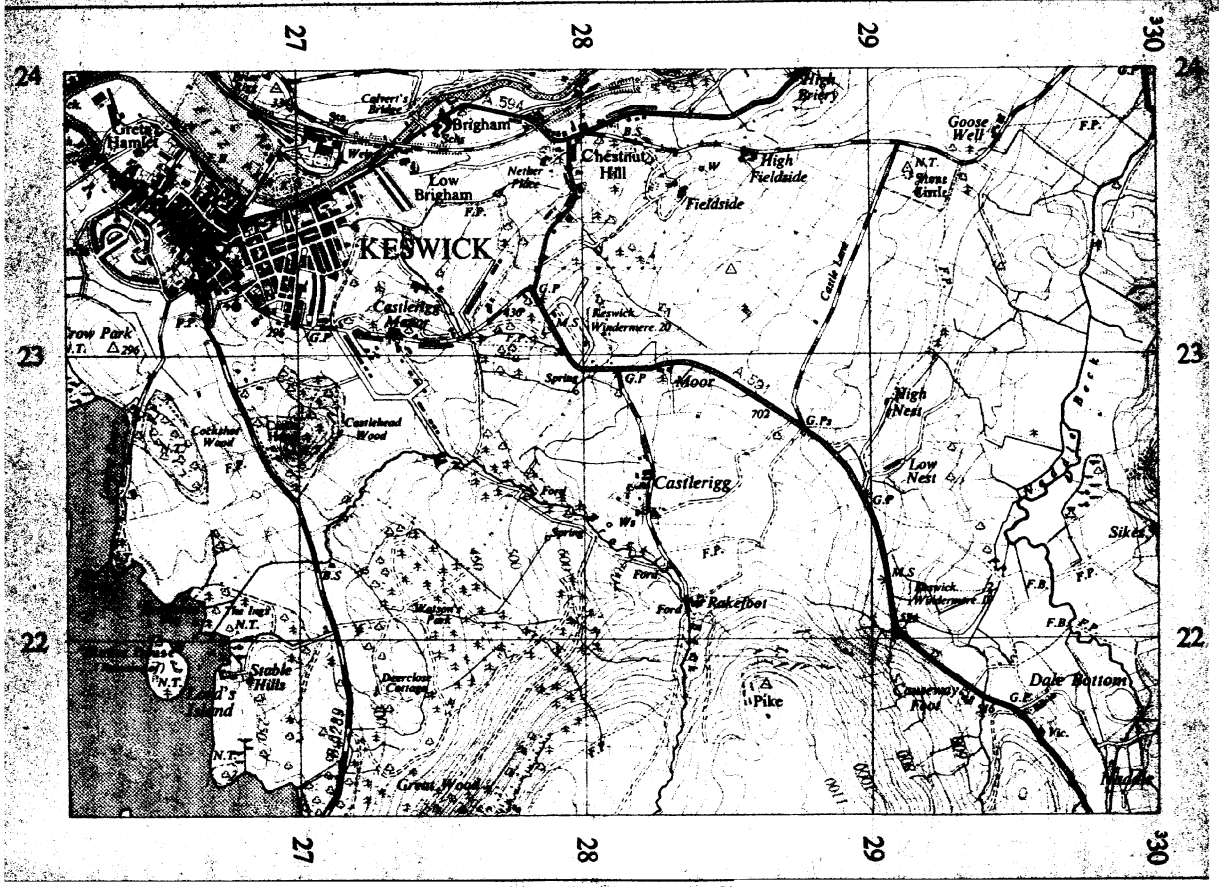
Much of what has been said about the Tourist Edition map of the whole Lake District will apply to the 2½-inch **Keswick** map (facing page 64) and the 1-inch **Sedbergh** map (facing page 64).

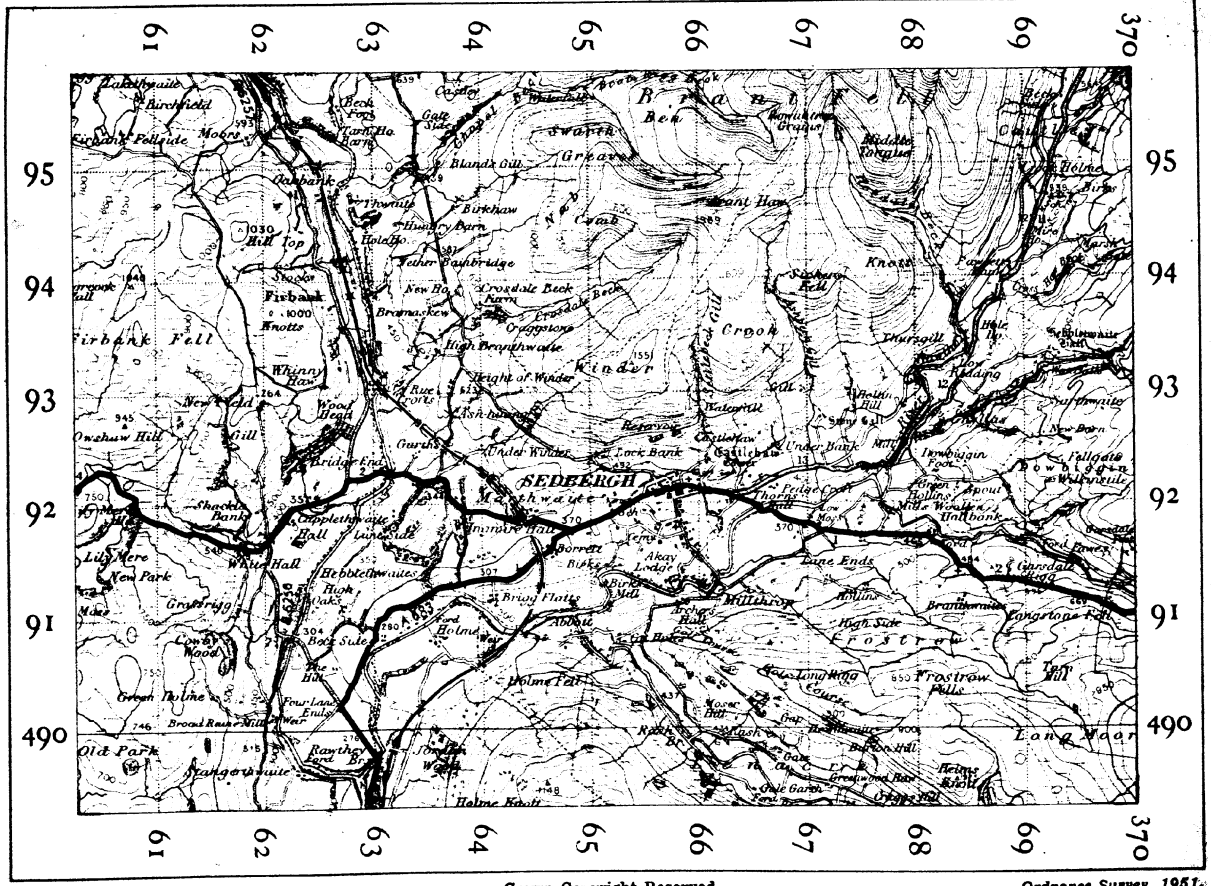
THE KESWICK MAP.—Points to note in this map are the drainage and the significance of the contours. The scale of the **Keswick** map should be compared with that of the 1-inch Sedbergh map. Particularly note the contours. Draw some topographical sections from each map, especially across the higher ground and consider the slopes thus shown. Compare the distribution of woodland, especially in relation to the contours and aspect. Why does the drainage pattern in the Keswick map appear relatively simple? What impression do the terms "**beck**" and "**ford**" give? Can you suggest reasons for the occurrence of the word "spring"? Suggest possible forms of land use, especially in relation to physical features. What do you think a town-planning expert might say in relation to the lay-out of Keswick? Note how the valleys and lowland control the routes, how settlement avoids the high land as well as the immediate neighbourhood of streams in the valleys. The nodality of Keswick is obvious, several routes meeting at this site.

The scenery of the Lake District attracts many tourists. Towns which are by no means large, and sparsely distributed villages, have adapted themselves to cater for these tourists. One of the larger centres is Keswick, on the edge of the lowland between Lakes Derwentwater and Bassenthwaite. Besides being a tourist centre, its nodal position enables it to act as a market for a sparsely-populated sheep-rearing and dairying region.

THE SEDBERGH MAP.—An important point in the Sedbergh map is the nodal position of Sedbergh, from which radiate many routes, including the railway. The contours guide us in tracing the valleys, which on the whole, are wider than those in the Lake District. They contain larger streams, with more developed flood plains, across which the streams meander. On the whole, settlement avoids the immediate neighbourhood of the streams, seeking the drier ground on the lower slopes of the upland. Except for Sedbergh, hamlets and isolated dwellings predominate. This is explained by the physical geography, which shows that mountain and moorland are characteristic of the region.

Between the Lune and Rawthey valleys is a stretch of wild mountainous region of the Lake District "fells", where the old hard rock predominates and furnishes poor soil. The radial, steep-sided, narrow valleys, which contain small "becks"


27
28
29
30
24
23
22
KESWICK
Brigham
Low Brigham
Chestnut Hill
High Fieldside
Fieldside
High Brier
Goose Well
Castlefield Manor
Castlerigg
Moot
Rakefoot
Pike
Stable Hills
Derwent Island
Great Wood
Cockshut Wood
Castlehead Wood
Watson's Park
High Nest
Low Nest
Dale Bottom
Sikes
Causeway Foot
Crow Park
Greta Bank
Keswick Windermere 20
A591
A594
Castle Lane
Ford
Spring
Ford
Ford
Ford



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Ordnance Survey, 1951.

flowing into the Lune and Rawthey, are not suitable for cultivation, and sheep-rearing is the main industry on the lower slopes. There is mixed farming in the main valleys, but, because of the predominating high land, facilities for this are limited.

Examination of contours shows that in the west altitude is less and that slopes are not so steep as in the area described in the last paragraph. Communication is easier here, and roads, both transverse and longitudinal, are plentiful, though they are of minor importance. They mainly serve villages and hamlets in the Lune valley, there being practically no settlement on the higher fells west of this river.

In the east and south-east of the map the fairly close spacing of the contours and their number denote the steep slopes of tolerably high land. There is a particularly steep slope west of the river Dee, and here there are no transverse roads. The south-east consists of limestone country, shown by the discontinuous lengths of stream indicating underground drainage and by the uniform plateau character of the moorland.

4. THE LINCOLNSHIRE WOLDS: A CHALK UPLAND

The appropriate one-inch sheets should be used, but a small-scale relief map (Fig. 25) is given on page 66.

Study of the Lincolnshire Wolds will give examples of some of the main features associated with chalk uplands. A tracing of the contours of the Wolds shows that the whole constitutes a belt of upland stretching from south-east to north-west, and continued across the Humber as the Yorkshire Wolds. In the west, the contours are close together, and the development of an escarpment is very clearly shown. Towards the east of the Wolds, the contours are much wider apart, and thus we see that there is a gentle slope in the direction of the lowland Marsh which skirts the North Sea.

The Wolds may be divided into three sub-regions, namely the North, Central, and South Wolds, and this division can be followed if we examine the contours fairly closely. The North Wolds have few streams, and along their western edge the escarpment is lower and more regular than in the other two regions. In the Central Wolds there are more streams, and thus there is a more clearly-defined valley system, especially on the gentler eastern slope. The escarpment is highest and best developed in the Central Wolds, where it is much fretted by the headwaters of small

streams which flow west to two larger streams, the Ancholme and Langworth, which are tributary to the Humber and Witham respectively. In the South Wolds the scarp gradually ceases to be a prominent feature, but there are several streams flowing respectively to the Witham and the North Sea. Consideration of the streams and their influence upon village sites affords sufficient contrast to justify threefold division, though each division has distinct characteristics in relation to the escarpment. The North and Central Wolds are separated by a transverse east-to-west depression which is utilised by the railways.

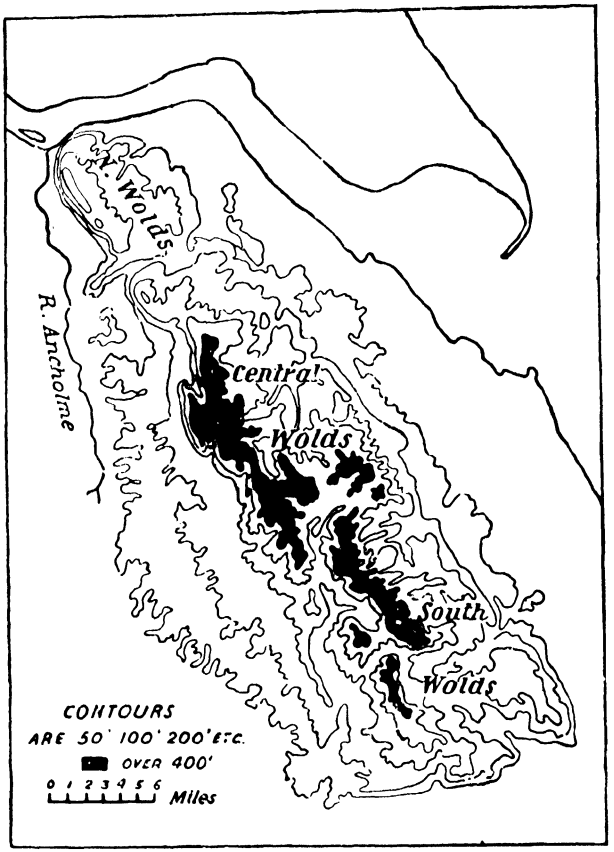


Fig. 25. The Lincolnshire Wolds.

If the valleys could be filled by the material which has been eroded in their formation, the Wolds would be a plateau, and the plateau character of the relief is evident in those parts where there are few or no valleys. The Wolds as a whole can be defined as a dissected plateau of relatively low elevation.

Now consider the streams. With the exception of the Bain, which flows to the Witham, the westward-flowing streams have little influence on the Wold topography, as they are merely the headwaters of streams which originate from springs along the Wold escarpment, where chalk rests on impermeable clay and supplies spring

water which cannot make way through the clay. This water fell as rain and soaked downward through the chalk as through a sponge. It oozes out as springs where the chalk touches the clay, as it cannot make progress through the impervious clay.

There are many villages along the escarpment. If a tracing of the village sites be made, it will be seen that there is a well-developed line of them following the direction of the scarp. They are sometimes called sub-scarp villages because their sites were largely due to the presence of springs at the base of the scarp. The scarp is not sufficiently steep to interfere with communications. Make a tracing of the roads and notice that there are many which are transverse routes linking up the eastern valleys and the bordering marshland with the Clay Vale west of the Wolds. The transverse roads generally take advantage of stream valleys, but there are important roads along the length of the ridge and plateau. Contrast such distribution of relatively easy routes with communications in the mountainous regions of the Scottish Highlands, where road construction has been very difficult and is absolutely dependent on the valleys.

Wold villages, apart from those along the scarp-base, are generally in the valleys of streams flowing to the North Sea or tributary to the Witham. Away from the valleys, there are practically no villages, though isolated farmsteads, known locally as " tops " and featured thus on the map, are found here and there on the streamless higher land of the ridge. The problem of water supply is here solved by sinking wells, and the water is often raised by windpumps, the symbol of which you will notice.

Practically all North Wold villages are in the west, near the sub-scarp springs, because no streams flow east from this part of the Wolds. If a tracing of the streams and valleys be made, it will be seen why the villages of the Central and South Wolds are more widely distributed. The blanks on a village-site tracing generally fit into the contours which enclose and mark the higher levels of the region.

There are no towns actually on the Wolds, though there are a few small market-towns on the borders. This shows that the Wold is essentially a farming region, and that the bordering market-towns are collecting centres for the farm produce. The villages are small, and this is explained by the fact that Wold farms are large, because the poor soil does not favour the intensive cultivation associated with smaller holdings. Soil of chalk and limestone regions is always poor, and some of the Wold is mantled by clay and sand left by the old-time ice-sheet. After the Industrial Revolution much was done to improve the soil of this region, which was previously largely given over to poor sheep pasture and rabbit warrens.

5. THE BANCHORY DISTRICT OF THE DEE VALLEY

This map (facing page 32) comprises part of the middle basin of the Aberdeenshire river Dee. The Dee valley on the whole lies upon crystalline schists flanked on both sides by large granite masses. The contours show the rounded character of hard rock surface scoured by heavy glaciation.

The map shows part of the main valley of the Dee, which is marked by incised meanders cut in the hard schists. This comparatively narrow valley is a contrast to the relatively wider valley of the tributary, the Water of Feugh, above Heugh-head. The Feugh valley is here along the boundary of granite to the south and schists to the north and is much wider. The meanders wander about more, and are connected with a network of minor drainage channels. Note the character of other valleys, *e.g.* those of the little burns (streams) in the south-east of the map are hanging valleys: they are above the level of the main valley, and produce small waterfalls where their streams descend to the lower land.

There are river terraces in the Feugh valley, showing that the stream has sometime flowed at a higher level. They are flat alluvial tracts above the present level of the stream, and out of reach of the highest flood level. They indicate that the river has deepened its bed since they were formed.

There are also deposits of glacial drift left by the ice-sheet which once covered this region. Eskers or gravel ridges occur, but these are too low to be shown by the ordinary contour lines. The fact that this valley has been glaciated is shown by the U-shaped cross-section. The meandering stream denotes that its slope is slight. There is very little vertical corrasion, but in places there may be some lateral corrasion of the banks, which will be balanced by deposition elsewhere. Thus shifting of the channel results, and the drainage is indecisive. This indecision is less marked below Heugh-head, where the rock is probably harder and the slope steeper.

The poor soil and the altitude of the uplands of crystalline rock explain the lack of settlement there. Note the forest: consider whether the trees are coniferous, deciduous or mixed woodland: if conifers, connect with the climate.

The contours show a good example of a tabular granite mountain south of the Dee, and marked by the re-entrant valleys of small tributary streams. Re-entrants are also well shown in tabular mountains south of the Feugh, and illustrate the steep-sided narrow valleys of immature drainage. (See Chapter VI.) Such torrential valleys are quite destitute of human settlement.

Note also the general absence of villages in the valley of the Feugh: the meandering stream and the likelihood of flooding explain this. An exception is the village of Strachan, where the slope of the higher ground approaches the stream.

Several roads converge on Banchory, which was an active market centre in the days when rural fairs were more important than at present. Both the Dee and the Feugh are bridged near Banchory, these bridges emphasising the nodality of this confluence township. Banchory is built on a southward-facing slope and protected from cold northerly winds by the adjacent hills: thus, it has developed into a health resort of some note. Banchory's situation on a southward-facing slope is typical of Deeside villages. The neighbouring heights are well wooded, and the forests furnish material for timber industries. The region is mainly a farming one, the chief crop being oats. Try to explain this by climate and soil. Some turnips are grown, both sheep and cattle being reared. Suggest which are more likely to be pastured on the lower hill slopes and which on the meadows of the Feugh flood-plain. Such points cannot be deduced from the map, but are suggested by it.

Note such names as weir, ford, bridge, mill, and associate them with the streams. Note, too, how the roads and the railway line follow the valleys and the better drained lower land, but avoid the actual streamside. Explain this, and consider why they do not follow the ridgeway or climb the slopes of the higher land. The sites of castles denote that the region has had historical associations.

6. THE CHEDDAR REGION OF THE MENDIPS

This map (facing page 32) in the north and east shows (1) part of the Mendip Hills, flanked on the western side by a portion (2) of the Axe basin, and (3) of the higher land of the Somerset plain.

The Mendips are a steep-sided smooth-topped plateau with north-west to south-east trend, and consist mainly of the porous carboniferous limestone, the lower ground bordering them being fertile red sandstone and marls. The Mendips have all the typical features of a limestone region, such as caverns, underground streams, swallow holes into which surface streams disappear and then reappear after an underground course, steep-sided gorges, and scarped slopes. The Cheddar caverns, cliffs, and gorge shown in the map are famous. Note how close the contours are in the gorge, along which a road winds.

The Cheddar Gorge, more than 400 ft. deep, has been cut in carboniferous

limestone. On the south side, the cliff is almost vertical, but in the north the slope is gentler and sometimes coincides with the dip of the limestone, that is, the slope at which the rocks are inclined from the horizontal. Throughout most of its length, the gorge is dry, but near the lower end a stream flows out of the rock. It is suggested[1] that the gorge is mainly due to underground water, which, by enlarging fissures in the limestone and by the solvent action of carbon dioxide, formed a cave, the roof of which fell in.

In a limestone region like the Mendips, the water circulation is mainly underground. This is because (1) calcium carbonate is very soluble in water (originally rainwater) containing carbon dioxide, (2) a highly developed system of joints is found in limestone rocks. The result is that joint-fissures develop on a large scale and assist the formation of caverns, like the well-known Mendip caves.

The absence of surface water has a peculiar effect on the topography of limestone regions, because when there is a minimum of surface erosion, the limestone forms tabular hills or massive plateaux, often bounded by a steep escarpment like that of the Mendips. Such plateaux have thin soil, and thus possess poor agricultural value.

Dry valleys are a feature of the Mendips, as in other limestone districts. They were probably formed during a period of heavy rainfall, possibly during or just after the Glacial Period. It has been suggested (1) that they were formed by glacial torrents when the rocks and soil were frozen, when it was impossible for water to sink into the rocks and give rise to springs, or (2) that either change of climate or uplift of the land, with resultant denudation of the neighbouring surface, led to lowering of the water table, a condition unfavourable to spring formation. "Water table" indicates the upper surface of water which saturates a porous rock like limestone.

The river Yeo, a tributary of the Axe, which drains into the Bristol Channel, rises from a spring in the scarp near Cheddar, but the scarp is singularly destitute of stream headwaters, a great contrast to the chalk scarp of the Lincolnshire Wolds. The Mendip scarp, however, is considerably fretted by streamless re-entrants known as combes. The Yeo, like its parent stream, has in parts been canalised, a fact shown by straight reaches. The straight drainage channels are characteristic of a marshy lowland. The frequent occurrence of the word "moor" here, and the absence of settlement, emphasises the low economic value of the river flood-plain.

[1] Professor S. H. Reynolds.

The higher parts of the Mendips have the flat-topped features of a plateau, intersected by several narrow, streamless valleys, which are utilised by roads. The site of an old Roman road is on the higher ground, following the practice of early times, when roads clung to the dry ridgeways and avoided the marshy, and often wooded valleys. Villages are absent from the Mendip upland, where, however, there are isolated farms, as in the Lincolnshire Wolds. Lack of water, except from wells, is largely responsible for the absence of village sites on the uplands. Cheddar, Axbridge, and three other fairly large villages lie at the foot of the scarp on the fertile red sandstone, and roads radiate from them northwards through the Mendip valleys as well as along the scarp border. Roads and railway, like the villages, avoid the river, and the alluvium of its flood-plain.

In the south-west of the map, where the sandstone and marls give higher land and fertile soil, there are several villages connected by longitudinal and transverse roads. These are relatively large villages often spread out along a road.

This map gives several contrasts in regions and their economic significance. On the whole it represents a farming district, engaged in dairying, mixed farming, and fruit growing. The chief regions are: (1) the plateau and scarp of the Mendips; (2) the Yeo valley, roughly parallel to the scarp; (3) the low plateau of the south-west.

7. THE TEIGNMOUTH DISTRICT OF DEVONSHIRE

The map given as frontispiece is that of the Teign estuary and the adjacent country. The estuary is a drowned valley of the ria type, and a spit has formed partly across its mouth, showing that deposition by tidal currents has been active. The narrowness of the passage from the sea into the estuary and the presence of sandbanks and mud-banks in the estuary afford evidence of the relatively small erosive power of the river. At the head of the estuary is marsh land which is gradually being extended seawards. Drainage on this low marsh is very indecisive and is partly artificial, including canals with locks to counteract the tidal effect.

The relief is that of a plateau surface dissected by stream valleys opening on either bank of the estuary. These valleys are narrow and steep-sided; their streams are " youthful," and in the valleys are more concerned with destructive than constructive work, though they carry some débris into the estuary.

Old red sandstone is the dominant element in the structure and gives a rugged character to the topography. This ruggedness is emphasised by cliffs along the

seashore. Close contours along the estuary sides mark the fairly steep slopes associated with a ria, though, especially along the northern bank, coastal flats have resulted from the preponderance of deposition over erosion.

The economic life is largely centred around the estuary. Teignmouth is a seaside resort and a fishing port. Newton Abbot is interested in kaolin from the neighbouring Bovey clay basin, and manufactures the famous " Devon " fire-grates from " china stone." Much china clay is quarried near Newton Abbot for export and is shipped from Teignmouth.

There are several villages in the valleys which open on the estuary, but the cliff-bordered coast has none, and on the plateau habitations are mainly in hamlets and isolated farms. Railway and main roads follow the coast and the estuary, but the plateau is no obstacle to roads of secondary importance. Newton Abbot and the village Kingsteignton are fairly nodal, but the economic importance of the estuary is emphasised by the major routes alongside it as well as by the situation and nomenclature of the villages. The occurrence of the name " Teign " is significant: Teignmouth, Kingsteignton, Bishopsteignton, Combeinteignhead, Stokeinteignhead. Compare with the Teignmouth map the coastal features, relief, drainage, incidence of communications, distribution of settlement, of the **Ventnor district** (Isle of Wight) map opposite page 24.

8. HINTS FOR CARTOGRAPHICAL AND GEOGRAPHICAL DESCRIPTION OF A MAP

In examinations, questions are sometimes set dealing with British Ordnance maps or similar foreign maps, especially French, German, and Swiss maps. Examiners may require a critical cartographical description of the map, or a geographical description of the area represented by it. A general geographical description may be asked for, or the description of some particular aspect, such as treatment of the physical or human geography, or parts of these, such as relief or drainage, settlement or communications.

In a critical cartographical description the map should be described and criticised as a piece of map-making, but description of the area represented by the map is not required. It is necessary to consider for what purpose the map is primarily intended, and then to determine how far the methods employed to represent geographical facts have succeeded in giving adequate information in an easily legible form. The section in Chapter I. on the " Problems of map making "

should be re-read, so that you will be able, after recognising these main problems, to consider whether they have been successfully solved. Suppose you have to give a cartographical description of a topographical map such as one of the Ordnance Survey one-inch series or a foreign map on the scale 1 : 50,000. If possible name the projection used, with a note on its suitability. This would give a lead for reference to representation of latitude and longitude, to sheet-lines and any indication of relationship with neighbouring sheets, the use of a grid and its coordinates in relation to the scale. Such details concern the skeleton of the map, but very thorough examination must be made of the means used to represent geographical facts, especially the use of graphic and easily read conventional signs and of suitable and legible lettering. By suitable lettering we mean that which will emphasise some geographical fact in addition to identifying a feature or place, for example, different types and sizes of lettering to show the relative importance or the population in round figures of towns. You must describe and criticise the method of depicting relief, noting the limitations of hill-shading or hachuring, the overcrowding or absence of contours, the use of hypsometric tints and suitability of colours used. Criticise the use of colours for water features, roads, woodland and other vegetation, etc. It may be helpful to adopt some standard of comparison, for instance, comparison with another edition of the same scale Ordnance map, or with a similar foreign map. Such comparison should not be overdone, and might be confined to points where the map criticised shows marked inferiority.

In a general geographical description of the area shown on a map, carefully hold the balance between the facts of physical and human geography, using the former to explain the latter. It might be well to start with a division into broad physical regions as suggested in Section 2 of Chapter V., and then work forward to the relief and physical features of each region, noting how these explain the location of settlements and communications. Is it desirable to introduce details of, say, geology, not shown on the map? Our answer would be, as a general rule, "No," though where the map shows intermittent drainage or dry valleys, we see little objection to referring to limestone.

CHAPTER VIII

DISTRIBUTIONAL MAPS AND THE GRAPHICAL REPRESENTATION OF STATISTICS IN GEOGRAPHY

1. DISTRIBUTIONAL MAPS

In the development of modern geography, and particularly of the map as a geographer's tool, the sketch map or diagrammatic method was largely used before more elaborate attempts were made to compile distributional maps from actual statistics. Sketch maps usually have no quantitative basis, either of scale or of data, and are rarely more than attempts to give some visual semblance to what would otherwise be simply verbal description. At best they can be regarded as little more than notebook summaries or attempts to counteract the " wooliness " of too verbose descriptions. They can be very misleading when applied to distributional purposes.

If the word " wheat " is written across the Canadian Prairie Provinces, it merely means that wheat is grown in certain parts of these provinces, and not necessarily everywhere where the letters W H E A T occur. On a map, to colour a district yellow for wheat, green for tea, may give the idea that the country is uniformly devoted to such crops, which is absurd. There may be lakes, deserts, or stretches of unfavourable soil, or there may be land too high to grow such crops. To write " Slavs " over a region may suggest that the people there are all Slavs, though there may be as many other people as there are Slavs.

Distributional maps based on definite data have considerable geographical and educational value, but even their value is limited. The commonest types are those indicating distribution of stock, crops, and population. During their compilation, it is necessary that certain physical maps should be consulted, for instance, maps showing relief and soils, climatic maps concerning temperature and rainfall. The best distributional maps are but cogs in a wheel, not the wheel itself. The statistical facts conveyed by them may help the geographer to apply his arguments and to trace his ideas of cause and effect, but in themselves they are not geography.

The statistical bases of such maps for England and Wales are usually official returns of the Ministry of Agriculture, of the Board of Trade, or Census Returns.

2. THE DOT METHOD

The dot method may be used for crops or stock or population when absolute, *i.e.* exact as distinct from average, figures are given.

An outline map showing the political divisions such as parishes or counties is needed: this serves as the basis of the distributional map. For guidance in placing the distributional data, a contoured map and a geological or soils map are required when a distributional map showing crops or stock is to be prepared. To assist preparation of a population map, an ordnance map showing town and village sites is desirable. The most carefully prepared distributional map cannot be other than approximately correct; however, there are degrees of approximation, and it is possible to construct such maps to show actual conditions with reasonable approach to general accuracy if not as regards minute detail.

We will illustrate the method by preparing a map showing the distribution of sheep in English counties south of the Thames. The statistics are Ministry (formerly Board) of Agriculture figures for a single year (1920), which were selected because the published acreage and live stock returns for that year give both the absolute numbers for each county as well as averages per thousand acres. The former will serve to illustrate the dot method; the latter will be used later (see page 80) for the shading method.

The statistics used are given below in a table which shows not only the number of sheep in the selected counties, but also the units of 5,000 sheep per county.

County.	No. of Sheep.	Units of 5,000 Sheep.
Cornwall	277,970	55·59
Devon	661,071	132·21
Somerset	288,737	57·75
Dorset	215,162	43·03
Wiltshire	182,122	36·42
Berkshire	78,800	15·76
Hampshire, exclusive of Isle of Wight	139,296	27·86
Isle of Wight	23,650	4·73
West Sussex	86,956	17·39
East Sussex	161,768	32·35
Surrey	32,550	6·51
Kent	679,984	135·99

The first step is to decide how many sheep each dot shall represent. If the outline map is merely a tracing from an ordinary atlas map, it is not large, and

thus there must not be too many dots to produce a blurred effect. A convenient unit seems to be 5,000. (Fig. 26.) There are two or three counties where few dots are required, and where there cannot be much real distribution shown.

Next, in each county pencil lightly the nearest figure indicating units of 5,000 sheep. Thus for Cornwall $277{,}970 \div 5000 = 55{\cdot}59$, and 56 should therefore be pencilled in (see the third column of the above table); similarly 132 for Devon, 58 for Somerset, etc. The pencilled figures assist the placing of the dots and can easily be erased if desired. Before placing the dots a map showing the physical features should be consulted.

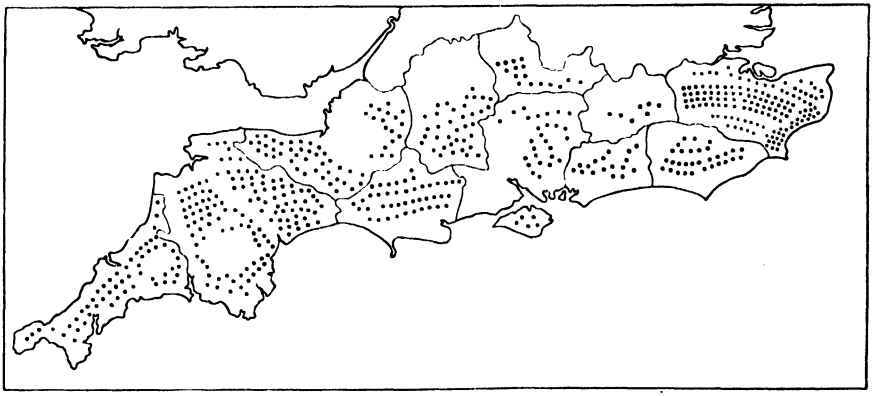


Fig. 26. DISTRIBUTIONAL MAPS—THE DOT METHOD.
To show the distribution of sheep in Southern England.

Certain areas are obviously little suited to sheep, while in others the flocks are very important. The New Forest in Hampshire should be avoided when placing the dots, and regions such as the Weald, the Thames valley, parts of Surrey and Kent near London, should have fewer dots than the rest of the counties concerned. Such regions contain some sheep, but are more important for cattle-rearing and tillage. The chalk uplands, especially the South Downs, will show heavy sheep density, so will the Romney Marsh district of Sussex, the South Down and Romney Marsh breeds of sheep being types which have formed the basis of flocks in New Zealand and other colonies.

This broad differentiation of regions favourable or unfavourable to the commodity being mapped is only relative on a county map, and is in no way so reliable as what is possible when the units are parishes or groups of parishes.

However, it gives a truer picture of actual conditions than regular spacing of dots all over the county. Such regular spacing is more comparable with the shading method, the limitations of which are noted on page 80. Compare Figs. 26 and 30.

When working on a map where the boundaries of parishes or groups of parishes are outlined, it is relatively easy to avoid assigning heavy density to unsuitable physical features or poor soils, but when counties are the smallest units, this is more difficult, especially on a small-scale map, where it is not easy to distinguish between the various geographical factors operating in so large an area as even a small county. It is obvious that in any particular county there can be no absolutely even distribution of, say, wheat or sheep. Most counties have considerable varieties of soil, and many have varieties of climate and relief. Such differences react upon the distribution of any commodity.

From reasonably large-scale physical and geological maps it is not difficult to identify areas where there will obviously be sparse distribution of crops or stock. Limestone or chalk uplands would normally show greater density of sheep than would be assigned to well-drained riverside meadows or to coastal plains such as the marshlands of East Lincolnshire or North Norfolk. The latter are more suited to cattle. Physical features must be carefully noted. For instance, in mapping the crops of Norfolk, the Broads must be avoided. In mapping crops for Cumberland, the mountains and lakes must be avoided; symbols must be concentrated in the Eden Valley and on coastal plains.

Even when the outline map shows only counties, it is possible to mark lightly in pencil where there is likely to be sparse distribution of crops, for instance, where mountains, lakes, or marshes occur. On such generalised maps, even when negative influences are eliminated, it is not feasible to compile anything more than an approximate generalisation. Commodity maps are of relatively little utility if they do not convey a quantitative conception, but they must also be qualitative in the sense that they differentiate between various areas where a particular crop or kind of stock is, or is not, extensively raised.

The preliminary elimination of negative regions, if we may so term them, will leave others where the dots can be placed, though rarely in uniform density. In Norfolk, after elimination of the Broads, the alluvial meadows of the Wensum valley, and the sandy Breckland of the south-west, more importance should be attached to the fertile loams of the north-east than to the heavier clays of the centre when " reconnoitring " before distributing the dots on a wheat map.

UNITS FOR THE DOT METHOD.—Care is necessary in selecting a suitable unit to be represented by each dot. There will be fewer cattle than sheep per 1,000 acres, and therefore this must be borne in mind when selecting the unit. For cattle, one dot might represent 25 or 50 according to the scale of the map. For sheep, one dot might represent 100 animals. For acreage of crops, similar discrimination must be observed. A very heavy crop, such as wheat in the Fens or East Anglia, must have dots to represent more acres under cultivation than would be used for a less common crop, such as sugar beet or hops. The dots must not be so numerous and so small as to be read with difficulty. We must avoid a unit which causes the dots to give the effect of a continuous blur, likely on a small-scale map if they indicate too few animals. On the other hand, if they indicate too many, the distribution may become too generalised and of little quantitative value.

The blurred effect is often noticeable in textbook reproductions of a map from official sources, such as year books. The map was prepared on a reasonably large scale, and the dots were quite legible not only on the original but on the officially reproduced copy. Permission may be given for reproduction of the latter in some textbook or journal, possibly on a smaller scale, and then the dots become less legible.

The other extreme sometimes occurs when the dot method is used for world distributional maps. Such maps, possibly drawn on an equal area projection like Mollweide (see page 150), are necessarily on a small scale. For the sake of legibility, few dots must be used, and thus a very big unit is necessary. If, as is sometimes the case, one dot is made to represent 100,000 sheep, only very generalised distribution is possible, and some small countries where sheep are reared may not find a place on the map. However, such diagrams are not without their uses if they are regarded as indicating the relative importance of sheep-rearing countries. Their practical geographical utility, however, is only small if they are not examined in conjunction with climatic and vegetation maps.

USES OF THE DOT METHOD.—The dot method can be used for many more purposes than would be possible with the shading method. (See page 80.) In a map of the coalfields,[1] dots can represent the sites of collieries, the size varying

[1] Used in *North England* by Professor Rodwell Jones, and in an article by him on "Commodity Maps" in the Spring 1922 number of the *Geographical Teacher*. This is a very valuable article, to which the present writer is indebted for ideas.

according to the number of men employed. Such figures are not always easily obtainable, but they are often the only ones available. It is not possible to obtain accurate figures relative to production. The number of men employed underground in the various pits can be gathered from Government figures published in Lists of Mines, but are of questionable value in estimating output, owing to the varying difficulty of working seams of different thickness. In preparing a map of a coalfield, outcropping coal-measures can be shown by colour wash or by stippling. Known concealed coal measures can also be suitably shown. It must be realised that such indications are merely incidents in a geological map, in no way absolutely indicative of output or of potential reserves. The pit, whether working or closed, is the unit of the coalfield, and the value of the dot method is evident in this connection. However, not only is it desirable to know the relative output of pits and the number of men employed in them; it would be equally desirable to map the depth of seams and any geological data, such as folding and faulting,[1] which affect ease in working and the possible use of cutting machinery. Where there is much faulting and folding it is very difficult to use cutting machinery.

In the United States, figures relative to coal production for certain counties are available, and the American county is a sufficiently small unit to enable an economic-map compiler to make reasonably satisfactory maps to illustrate coal production.

Dots can indicate the sites of fairs or of markets[2] in an agricultural region, or of co-operative factories in a dairying country such as Denmark. Various sized circles, which are adaptations of the dot method, can be used to denote utilised and available hydro-electric resources[3] in a country like Sweden or Finland. In these cases, where it is obviously necessary to indicate absolute figures, the shading method is not suitable.

[1] Folding occurs when rocks are crumpled into a series of ridges and furrows. A fault is a fracture which causes rocks to slip out of their normal position.

[2] Used in a paper on "The Livestock Markets of England and Wales," by R. E. Dickinson and H. C. K. Henderson, published in *Geography*, September 1931.

[3] Used in *The New World* by Dr. I. Bowman to show the water-power resources of Sweden; and by Dr. H. A. Matthews in "Notes on a Water Power Map of Eastern Canada," published in the Summer 1923 number of the *Geographical Teacher*.

3. THE SHADING METHOD

The shading method may sometimes be useful for crops and stock when average figures per unit area are given. According to this method, distribution is shown by different tints of colour layers or by distinctive methods of black and white shading. Such methods may be found suitable where only average statistics are available, for example, so many cattle or sheep per 1,000 acres, or a percentage area under, say, wheat. If the dot method is used in such cases, it may not be realised that the maps are concerned with averages. Hence, a small area with high density may appear more important than a larger area with moderate density but producing an appreciable total of the stock or crop in question.

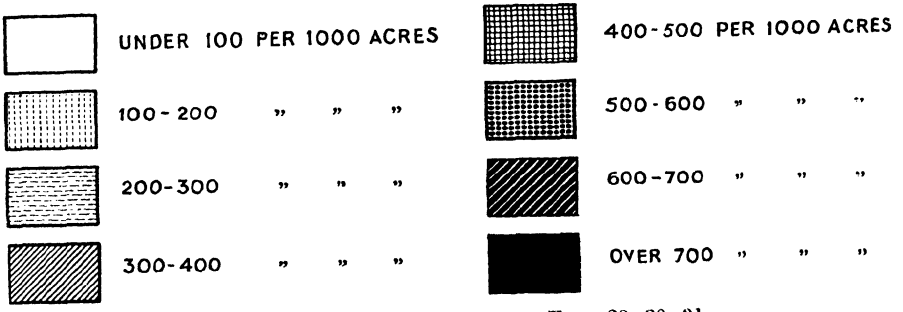


Fig. 27. KEY TO SHADING USED IN FIGS. 28, 30, 31.

The weakness of the shading method, whether for averages or absolute figures, is that distribution appears uniform over the whole area. In the distributional map of a county or large island, no account can be taken of waste, or relatively unimportant, land, such as desert or moorland, where, probably, no crops at all are grown. The shading method gives the impression that, say, wheat is as important in such areas as in the rest of the region. A compromise might be made by placing some symbol where such lands of negative value occur, and by noting that they do not really affect the density. This device, however, lacks concrete reality, and would not be easy to follow in reading the map.

If the shading method is followed, the basis, as in the case of the dot method, is an outline map of administrative divisions for which statistics are available, *e.g.* counties, parishes or groups of parishes. Suitable units must be selected,

e.g. for cattle, say, under 100, 100-125, 125-150, 150-175, 175-200; for sheep, under 100, 100-200, 200-300, 300-400, etc., per 1,000 acres. A key to the shading is constructed similar to Fig. 27. If colour is used, it is well as far as possible to select tints of one colour rather than to employ several colours. If provision must be made for many different figures, varying tints of similar colours, such as brown and yellow, might be used, the darkest tint for the highest density.

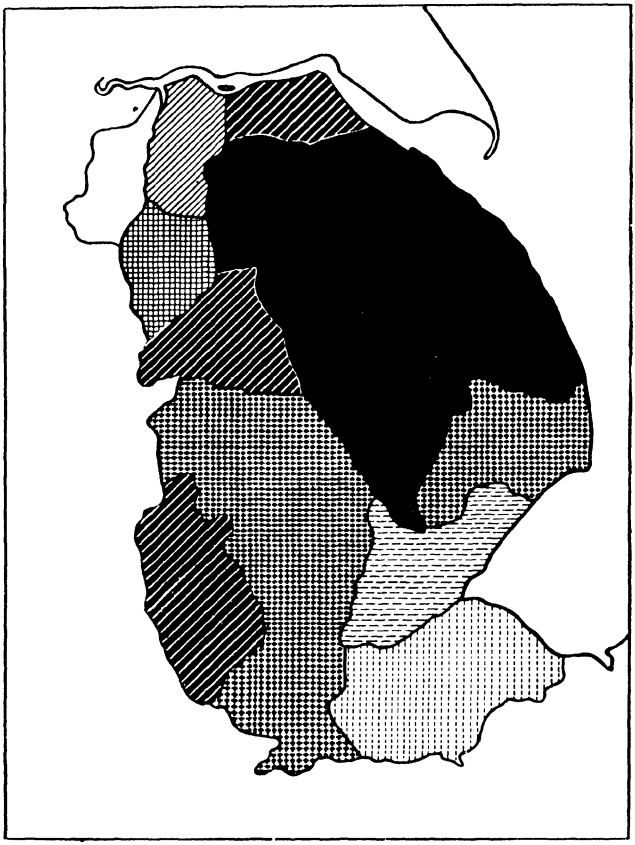


Fig. 28. DISTRIBUTIONAL MAPS—THE SHADING METHOD.
To show the distribution of sheep in Lincolnshire.

It is a good plan to pencil lightly the figures in each division. This prevents mistakes, and the figures can be easily erased when the map is finished. Compare the map (Fig. 30) showing sheep distribution for certain counties with that made by the dot method (Fig. 26) for the same counties.

The map shown as Fig. 28 makes use of the Petty Sessional Divisions of Lincolnshire. These are combinations of parishes, and were used because during certain years the Ministry of Agriculture statistics were published for such divisions. In a generalised map of the whole or part of England, statistics for counties might be used. These are always available in the published

returns of the Ministry of Agriculture. Parish statistics are not published separately and can only be obtained by special arrangement with the Ministry. They are best for a map of the whole or part of a county, as more accurate results are possible in a map where parish statistics are used for the shading method. A map based on Petty Sessional returns is a compromise, as such divisions may not readily coincide with physical regions. In Lincolnshire it is possible to correlate the physical regions with these divisions with some measure of success. Fig. 29 shows Petty Sessional divisions, with sheep per 1000 acres.

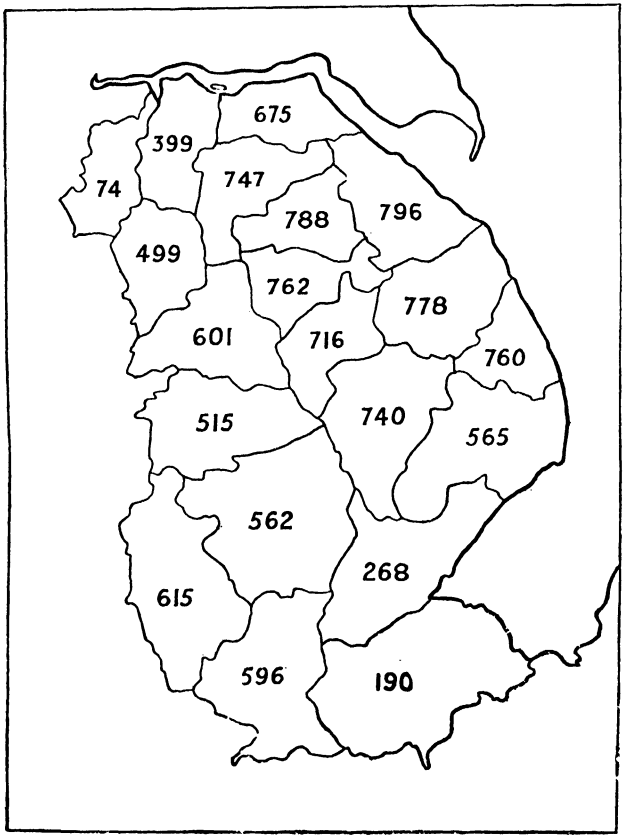


Fig. 29. DISTRIBUTIONAL MAPS.
Data for Fig. 28.

The main natural regions of Lincolnshire are the Marsh, skirting the Humber and the North Sea; the Wolds; a low boulder clay plateau between the Marsh and the Wolds; the Mid Clay Vale west of the Wolds and east of the limestone uplands whose scarp is known as the Lincoln Edge; the Vale of Trent; the Isle of Axholme; the Fenland. The Petty Sessional Divisions are sufficiently distinctive to enable us to gauge that Fig. 28, constructed from their data, emphasises a distribution of sheep

broadly representative of the natural regions. Thus, there is greatest sheep density on the Wolds, the boulder clay plateau, and parts of the Marshlands; least density on the drained Fenland and the Isle of Axholme.

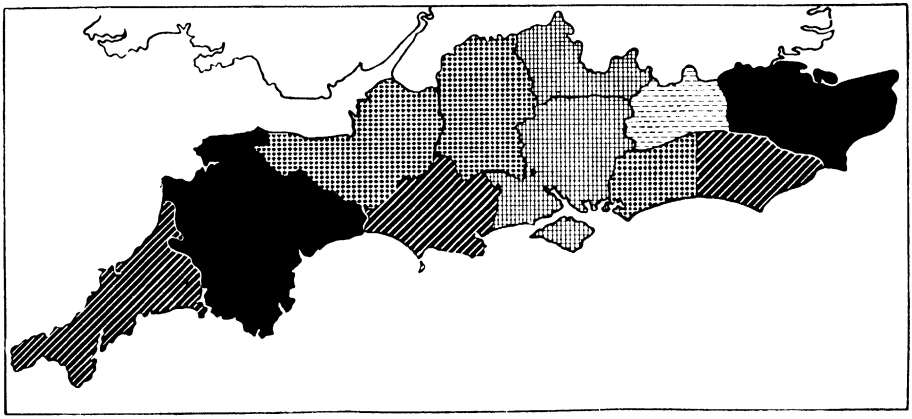


Fig. 30. Distributional Maps—The Shading Method.
To show the distribution of sheep in Southern England. (Average.)

The following figures (*a*) as an average for a period of years and (*b*) for a single year, on which Figs. 30 and 31 are based, are instructive in emphasising certain defects of the shading method.

District.	(*a*) Average.	(*b*) 1920.
Cornwall	619	455
Devon	709	569
Somerset	520	354
Dorset	660	476
Wiltshire	598	285
Berkshire	418	232
Hampshire, exclusive of Isle of Wight	455*	235
Isle of Wight	428*	343
West Sussex	524*	319
East Sussex	646*	467
Surrey	211	135
Kent	1248	963

Average is per 1,000 acres of crops and grass, and is for three years 1911-13, except the administrative "counties" marked *, for which the average is for two years 1912-13.

Compared with Fig. 26, which is based on the absolute number of sheep in each county according to the 1920 figures, the shading method map shows an apparently equal distribution throughout a county, including areas like the New Forest, where there are few sheep. To appreciate the shading, it is necessary to visualise the significance of the different shadings shown in the key (Fig. 27), and this is less easy than studying well-placed dots. The figures for 1920 are considerably lower than the averages, but the relative importance of the various counties as regards sheep is about the same. Owing to arrangement of the scale, Devon in the average map seems almost as important as Kent. This is not so, and if

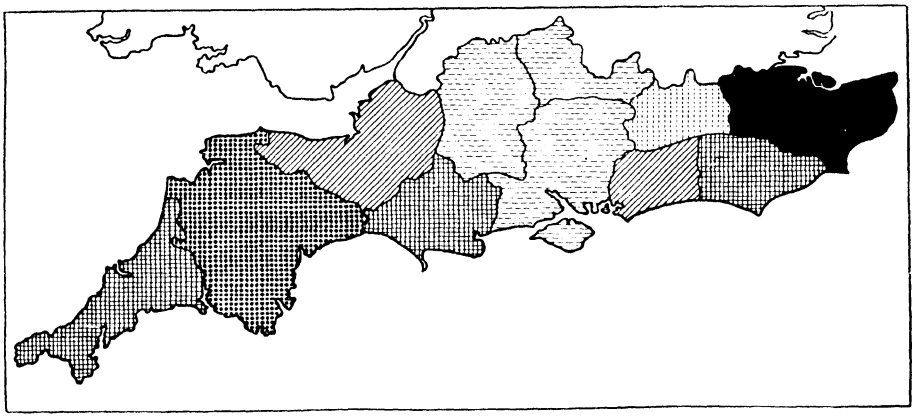


Fig. 31. Distributional Maps—The Shading Method.
To show the distribution of sheep in Southern England. (For 1920.)

one or two other shadings had been added, such as for *over* 800 or *over* 1,000, the prominence of Kent would have been more marked.

4. POPULATION MAPS

Statistics for a population map are obtained from census returns. Like crop and stock maps, population maps may represent either the number of persons per unit area or absolute figures derived from the actual population of towns and villages. In the former case, the shading or colour layer method is generally used; in the latter, use is made of the dot method or of some other type of symbols. In population maps the shading method has the disadvantage of giving a sense

of uniformity to the distribution, and takes no account of the actual site of settlements. The average for unpeopled moorlands like those of the Pennine plateaux is apparently the same as that for the more fertile dales with their villages and small market towns. This misleading uniformity is very apparent on small-scale maps, where it is not possible to make any distinctive symbols for towns.

The dot method, if the scale of the map is sufficiently large, and if a suitable unit is assigned to the dots, is more definite and more graphic. It has a concrete aspect, for we are dealing with the actual number of people and with actual sites. The best basis for a population map where the dot method is used is a one-inch or half-inch Ordnance map on which the sites of villages are shown with reasonable clarity. The general location of habitations and the sites of churches are shown, and dots can be placed to coincide with these.

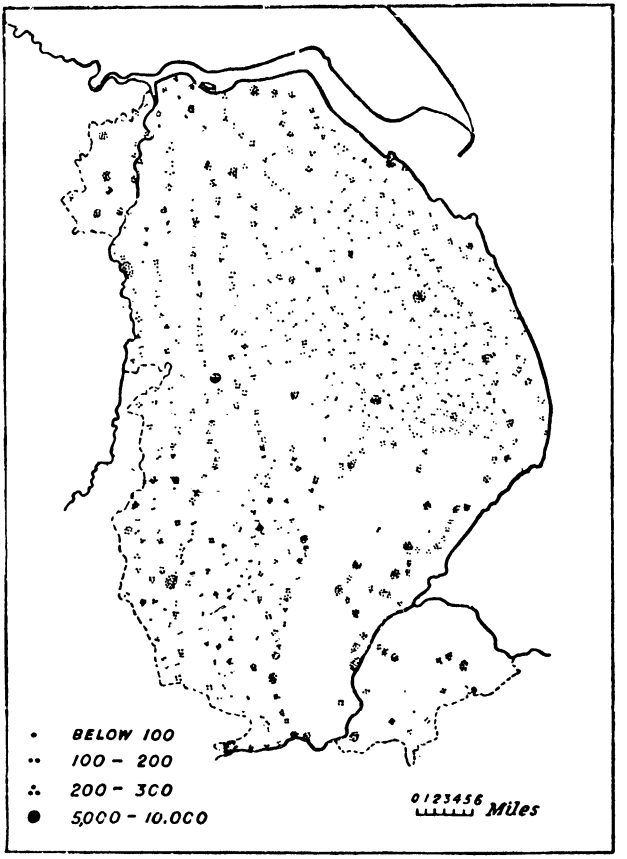


Fig. 32. Distributional Maps—The Dot Method.
To show the population of Lincolnshire, 1801.

It is important to select the unit carefully. For a rural area, a dot might represent a hundred, or perhaps two hundred, people, according to the size of the villages. These dots are put where the habitations occur, and it is possible to distribute

them in a fairly accurate way on a large-scale map. When preparing a skeleton tracing from the Ordnance map, it is well to pencil-in lightly the habitations. The pencilled marks can afterwards be erased. If the area is mainly urban, or if any large towns occur so as to make it impossible to use the normal sized dots, other symbols must be used. Dots of varying sizes might represent places with 1,000, 5,000, or 10,000 people, and special symbols such as squares or diamonds might be used for large towns.

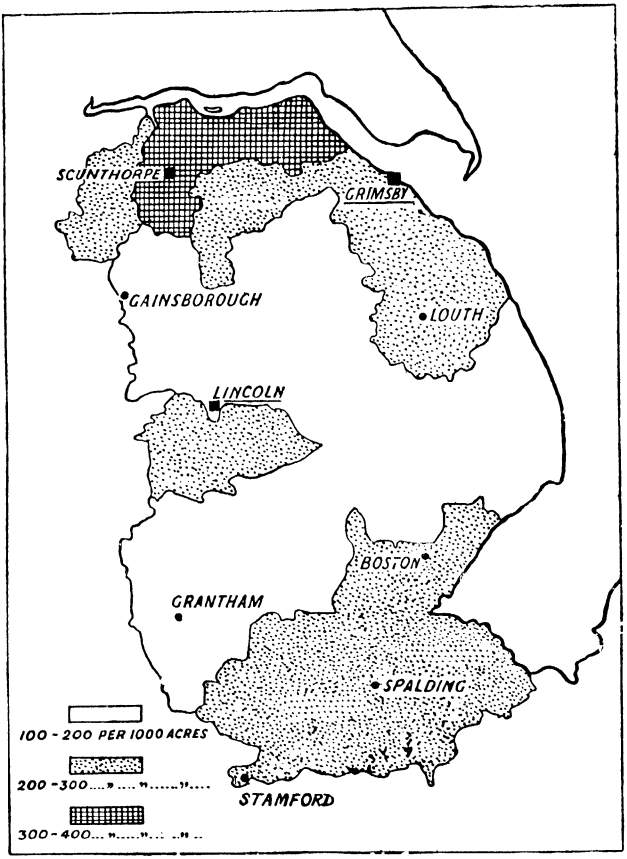


Fig. 33. Distributional Maps—The Shading Method. To show population of Lincolnshire, 1921. Towns are not included in density shown by shading. A black dot indicates towns of 10,000 to 20,000 inhabitants; a black square 20,000 to 50,000, and over 50,000 if names are underlined in addition.

A combination of the dot and shading methods is possible if we employ shading for averages without the inclusion of towns of a certain size, say those of 10,000 or 20,000 people upwards, merely using certain symbols for these larger towns. This method is possible for an area mainly rural, but with a few fairly large towns. It could be applied to Lincolnshire or Kent. (Fig. 33.)

Note.—Fig. 32 is based on the census for 1801, Fig. 33 on that for 1921. The 1801 figures were chosen because the population was then essentially rural.

Some population maps are constructed on a principle similar to a combined contoured and colour-layered relief map. On the map lines known as *isopleths* pass through places with the same unit of population, *e.g.* hundreds, thousands, etc., according to relative density in the region, and in principle resemble contours. Between the isopleths various tints of selected colours give the layer effect. This method is used for the O.S. population map of Great Britain on a scale of 1/M based on the 1931 census, and it must not be confused with the shading method. In the latter the boundaries of the various kinds of shading are those of a parish or other political division, but in the isopleth method the isopleths are the boundaries of various colour-layer tints.

5. LIMITATIONS OF DISTRIBUTIONAL MAPS

Distributional maps are frequently important visual aids in grasping general ideas. It would be very difficult to gain such ideas from mere columns of figures. However, there is danger that any distributional map may be taken too literally.

The value of statistics varies greatly. Distributional maps for crops and stock have only limited value, whatever statistics are used. The Ministry of Agriculture returns are for the whole year; they are supplied by individual farmers, whose returns are then grouped according to parishes. But in many parishes cattle are pastured during the summer and sent elsewhere to be fattened in fold-yards during winter. To give a truer picture, winter and summer stock maps would be desirable, but this is impossible, because such seasonal figures are not available. Numbers vary greatly from year to year, and a map founded on a single year's figures may not be in accord with normal conditions. Hence, it seems that from some points of view, maps might be better if based on statistics for an average term of years, say five. This would counteract any abnormal conditions due to an exceptionally good or bad year for crops or stock, and to some extent would allow for the effect of crop rotation. Averages may give a sense of artificiality and lack of reality, but to some extent this can be counteracted by special maps for abnormal years.

Population maps are based on census returns which are made once in ten years, and which for some districts may be misleading. Census figures for public institutions, barracks, holiday resorts, dormitory villages or suburbs, have obvious limitations, and deal with abnormal distribution of population which has little economic or geographical basis. A dormitory suburb or village is where workers in a city or industrial centre live and sleep, but their numbers have not the same

significance as though they were counted where they work. People living, possibly temporarily, in barracks or public institutions such as prisons or asylums, are of no economic importance to a district, and merely swell the population artificially.

Population maps compiled to represent so many persons per square mile, and prepared on the colour-layer or shading method, can be more misleading than similar maps for stock or crops, misleading as these often are. This is particularly the case when figures for several large towns are included in the average densities, or when a densely-populated district and an area of little economic value occur in the same administrative unit and jointly affect the average.

The only reliable distributional maps are those (1) based on wisely selected figures, whose accuracy and reliability have been carefully checked, and (2) compiled in correlation with the physical, and, if necessary, with the weather or climate map.

Advanced students may with profit consult the Ordnance Survey Agricultural Atlas of England and Wales. The maps are compiled on the dot method, but only for a single year. They are reductions of a map based on large-scale county maps showing individual parishes, the statistics used being for such units. Thus, the data are sufficiently detailed. The maps are on transparent paper, and in a pocket at the end of the atlas are relief, rainfall, and geological maps to use with the transparencies.

Comparison of the first and second editions of this atlas will show how maps based on figures for single years differ.

6. THE USE OF STATISTICAL DIAGRAMS IN GEOGRAPHY

Climatic statistics form the basis of various types of maps. Mean monthly temperature, mean monthly pressure, form the basis of isotherm and isobar maps, for which purpose they are reduced to sea-level. They represent average conditions, whereas the ordinary weather map represents actual conditions at a given time. Mean monthly, mean annual, and mean seasonal rainfall figures form the basis of rainfall maps.

The practical construction of such maps resembles that of contoured maps, the figures for the various meteorological stations corresponding to the spot heights. In addition to their use for climate maps, temperature, pressure, and rainfall figures are used for curves and other graphs.

Apart from their use for distributional maps, statistics give the raw material for graphs which are used for comparative purposes. A curve can show the relative number, say, of sheep in different counties or countries, the number of acres under a particular crop in different regions, or the relative acreage under different crops in the same region. Such comparisons of different area can also be made by the use of lines of different lengths, or figures, such as oblongs and circles. Similar methods, both curves and figures, can be used to compare the value or volume of a country's exports and imports, or for almost any quantitative purpose.

The idea of statistical diagrams is to show at a glance the significance of the statistics without reference to the exact figures. Such diagrams, however, present the facts approximately. In comparing the population of different countries, we generally talk of millions, and therefore a diagram constructed for this purpose will show the nearest figures to exact millions, or possibly to half-millions in the case of smaller countries.

Statistical diagrams, for example "pie" graphs, are sometimes drawn on a map, forming what is known as a "cartogram." On each province on a map of Canada there could be drawn a "pie" graph showing the percentage value of each mineral produced in that province, other "pie" graphs might show percentage areas of cultivated crops, or population percentage engaged in urban or rural occupations.

Preliminary adjustment of statistics is necessary. Examples of such adjustment will be given in the following paragraphs.

In addition to the adjustment of the statistics, it is necessary to examine the latter carefully in relation to the size and scope of the proposed diagram. To make this clear, we will consider some of the types of diagram usual in connection with statistics with geographical bearing.

The following table, showing acreage under beet in Great Britain for certain years, will serve as a basis:—

Year	Acreage	Year	Acreage
1924	22,637	1927	232,918
1925	56,243	1928	178,047
1926	129,463	1929	230,553

Such numbers might be represented by any one of the following ways: (1) by a curve showing fluctuations from year to year and similar in principle to temperature curves; (2) by straight lines of lengths proportionate to the numbers; (3) by rectangular figures proportionate in area to the numbers; (4) by sectors of a circle, the angle opposite the arc of each sector being proportionate to the numbers.

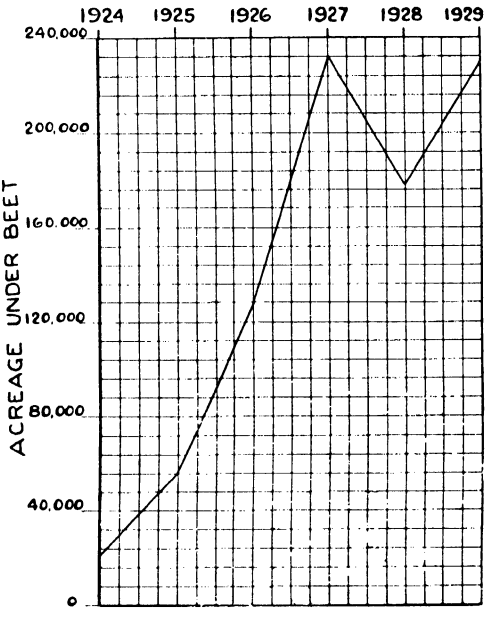


Fig. 34.

Example 1. Squared paper is used for the curve. (Fig. 34.) The vertical scale represents quantities, the side of one small square representing 8,000 acres. "Time" is conveniently measured horizontally along the base-line. Horizontal distances enable a scale of years to be read, and in this figure, intervals of four squares have been used between each year. Zero gives the base line, as the first vertical reading will be only a short distance away from zero.

The statistics are adjusted to show the nearest numbers representing 8,000 acres, the actual acreage being divided by 8,000, giving for:—

Year	Units of 8,000	Year	Units of 8,000
1924	2·8	1927	29·1
1925	7·0	1928	22·3
1926	16·2	1929	28·8

We begin the diagram by marking on the vertical line representing 1924 a small dot rather more than half-way along the side of the third small square from

zero. (Fig. 34.) On the 1925 vertical line we make a dot 7 squares from zero. Similar procedure is observed for the other years, and the various dots on the vertical lines are connected. Though termed a curve, this diagram consists of straight lines, which are desirable to denote the drop from 1927 to 1928, and the rise from 1928 to 1929.

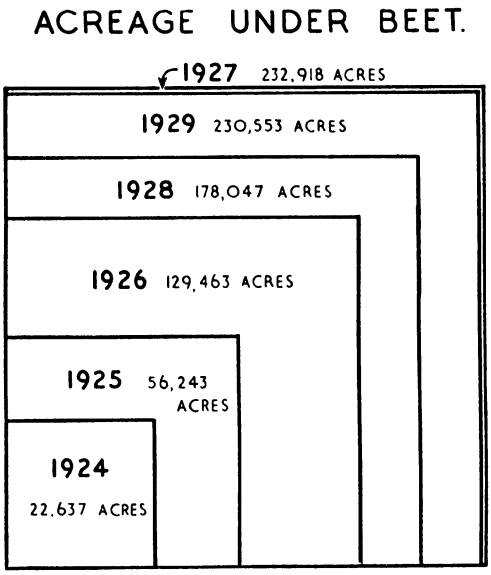


Fig. 35.

In this diagram it was possible to take the base-line from zero, as the first reading was not many squares above zero, and the highest reading required less than 30 squares above zero; thus, a diagram of convenient size and with reasonably large scale was possible. It is always desirable to draw such diagrams on as large a scale as the paper permits, and scale can usually be gauged by careful consideration of the base-line, which should be as near as possible to the lowest figure in the statistics. If the lowest number had been that for 1926, the base-line might have represented 120,000.

EXAMPLE 2.—For a diagram where the proportions are indicated by straight lines, we might use $\frac{1}{10}$ inch squared paper and take as our unit 4,000 acres, using 5·6, 14·0, etc., as our figures, each 4,000 acres being represented by one-tenth of an inch. Thus, nearly $\frac{6}{10}$ inch would represent figures for 1924, 1·4 in. for 1925, etc. Or, we might take 20,000 acres, represented by 1 in., as the basis, and draw lines of 1·13, 2·81, 6·47 in. respectively. Generally, in preparing such statistics for use in the diagram three significant figures are considered.

EXAMPLE 3.—In drawing the rectangular figures, one square with $\frac{1}{10}$-inch scale represented 400 acres. (Fig. 35.)

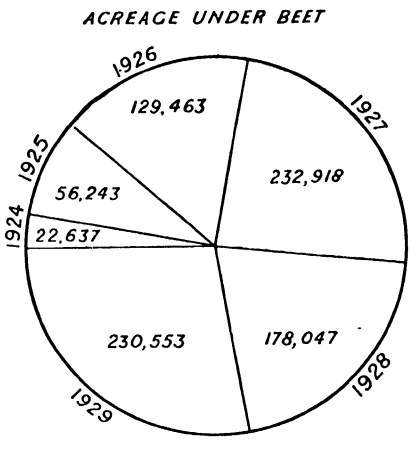


Fig. 36.

EXAMPLE 4.—The "wheel" or "pie" diagram also gives the actual sense of area. It is made by drawing a circle, at the centre of which are made angles proportional to the acreage. (Fig. 36.) This is done by considering each year's acreage as a fraction of the total acreage for the series of years. These fractions, when applied to 360°, *i.e.* a circle, give the angles for the various sectors. Such a diagram only shows proportion, and not the actual acreage as shown by the curve or straight line.

If a circle be divided into 100 parts, it is easy to adopt method 4 for percentages.

6. USES OF VARIOUS TYPES OF STATISTICAL DIAGRAMS

The type of diagram noted under (1) is largely used for climatic purposes, such as representation of temperature and rainfall statistics. Mean monthly temperature and mean monthly rainfall can be easily shown. In such graphs the months form the abscissae, the temperature or amount of rainfall the ordinates. Temperatures are usually shown by actual curves. In rainfall diagrams, the dots are often connected by straight lines, and are thus given a prominence which is not desirable in the case of a curve. Such methods are appropriate, because temperature is continuous, while rainfall is discontinuous.

The mean monthly temperature curve is useful in gauging extremes of temperature. Temperature curves for a single month as well as for a year are possible, each day instead of each month being marked horizontally along the zero line. Similarly, temperature curves can be drawn for hourly readings throughout any day. Monthly or daily pressure charts are in like manner constructed from barometrical readings, but there has been considerable development in self-recording instruments which automatically record curves of temperatures and pressures, and thus enable observations of maxima and minima to be made.

Mean monthly rainfall can be plotted absolutely, or as a percentage of the mean annual fall. The latter method shows at a glance the incidence of seasonal rainfall, and is frequently employed in the diagrams of advanced books like

Kendrew's *Climates of the Continents*, and his *Climate*. The seasonal character of rainfall is an important aspect of climate in relation to crop production, and such diagrams are particularly useful in this respect.

As a rule, temperature and rainfall graphs should be plotted on separate diagrams. The great difference in the vertical scale would generally result in unduly cramping the temperature, though a compromise might be attempted by placing the vertical temperature scale on the left of the diagram, and the rainfall scales on the right. Two or more temperature curves may be plotted on the same diagram for comparison, but care is necessary to prevent confusion and some distinction is usually made in the character of the curve lines, *e.g.* continuous, discontinuous, or dotted.

Rainfall is sometimes shown by lines on the plan of (2) noted on page 91, or by blocks on the same principle. There is, however, no advantage over the curve, and blocks take longer to draw. For a single station, a combination of temperature curve and rainfall line on the same diagram sometimes might be graphic. (Fig. 37.) Vertical scale for temperature would be reckoned on the left and for rainfall on the right of the paper. In many cases, however, such diagrams would not be very clear, and there is the disadvantage of having to read two scales. A better plan is separate diagrams. The rainfall graph might be made on transparent paper for superposition on

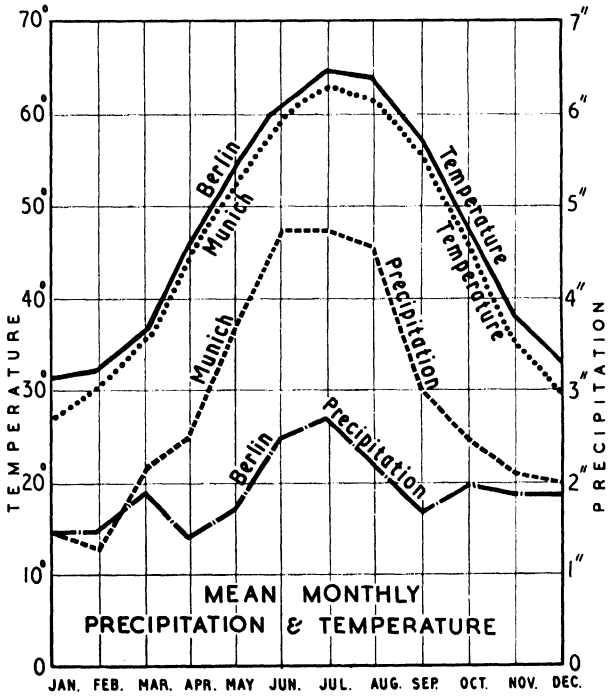


Fig. 37. See tables on following page.

the temperature if it is desired to read them in combination, though there should be little difficulty in correlating two ordinary graphs without superposition.

The curve method (1) is useful for showing statistics illustrating economic and human geography where the time element is concerned. For instance, fluctuations in population of villages or towns shown by a number of census returns, imports or exports for a series of years, output of coal mines or of oil-wells for a period.

TABLES FROM WHICH CURVES IN FIG. 37 ARE PLOTTED.

BERLIN (Alt. 164 ft.).

Month	Temp.	Precp.	Month	Temp.	Precp.
Jan.	31·3	1·5	July	64·4	2·7
Feb.	32·5	1·5	Aug.	63·3	2·2
March	37·0	1·9	Sept.	57·0	1·7
April	45·9	1·4	Oct.	48·2	2·0
May	54·9	1·7	Nov.	38·1	1·9
June	62·1	2·5	Dec.	32·7	1·9

MUNICH (Alt. 1739 ft.).

Month	Temp.	Precp.	Month	Temp.	Precp.
Jan.	27·3	1·5	July	63·0	4·8
Feb.	30·4	1·3	Aug.	61·5	4·6
March	36·1	2·2	Sept.	55·4	3·0
April	45·3	2·5	Oct.	46·0	2·5
May	53·1	3·9	Nov.	35·6	2·1
June	59·7	4·8	Dec.	28·6	2·0

Both are Central European types of climate. The altitude of Munich largely accounts for its lower temperatures and causes some relief rain. However, it is rather more accessible to Atlantic influences than is Berlin.

Methods (2) and (3) are useful for quantities when stressing the time element is not important, as for the relative proportion of different commodities in a country's total exports or imports. The circle method (4) on the whole is quicker, once the relative percentages or proportions have been reckoned, and is less cumbersome.

Comparison of Figs. 34, 35, 36 will show the relative advantages of the various methods. If we wish to stress the various years, method (1) seems best, if the acreage, perhaps method (4) has advantages, though in this respect method (1) is useful.

Note 1.—Figs. 27-29, 32, 33, in this chapter, and Fig. 25, are, with permission of Messrs. G. Routledge & Sons, Ltd., based on diagrams in the writer's *Eastern England.*

Note 2.—For very detailed treatment of various types of statistical diagrams see *Maps: Topographical and Statistical* by T. W. Birch.

CHAPTER IX

WEATHER MAPS

1. EXPLANATION OF SYMBOLS ON WEATHER MAPS

Before the War of 1939-45, daily papers published a **weather map,** which summarised the existing weather conditions over the British Isles and Western Europe, and gave a forecast of weather to be expected during the next twenty-four hours. In England the official weather maps, on which newspaper maps were based, are issued by the Meteorological Office. This is a Government Department under the Air Ministry, and employs a staff of highly trained scientists whose work is to compile and interpret the weather maps and to study weather conditions generally.

The official weather maps are very interesting, and their cost is not great. In peace time the Meteorological Office supplies them for a relatively small subscription. In order to derive the greatest possible benefit and enjoyment from perusal of these maps, careful study of the official handbook, *The Weather Map* (H.M.S.O.), is recommended.

An explanation of the various symbols used on weather maps is given below. Further information regarding symbols is given in an Air Ministry publication entitled *Instructions for the Preparation of Weather Maps* (H.M.S.O.). The daily weather maps published by the Meteorological Office are more detailed than the smaller maps reproduced at the end of this chapter, on which Beaufort symbols (explained on p. 96) are used.

General

Barometer. Isobars are drawn for intervals of two millibars.

Wind. Arrows fly with wind. Number of feathers indicates Beaufort Force. Note where half-sized feathers occur. Calm is indicated by circle outside weather symbol:—◎.

Temperature is given in degrees F.

Weather Symbols:—○ Clear sky. ◔ Sky less than $\frac{3}{10}$ clouded. ◑ Sky $\frac{4}{10}$ to $\frac{6}{10}$ clouded. ◕ Sky $\frac{7}{10}$ to $\frac{9}{10}$ clouded. ◍ Overcast sky. ● Rain falling. ✱ Snow. ✱ Sleet. ▲ Hail. ≡ Fog. ≡ Mist. ⊤ Thunder. ⊻ Thunderstorm.

The Beaufort Wind Scale

Beaufort 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 ...		28	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		69	Very rarely experienced; accompanied by widespread damage.
12	Hurricane		above 75	

These velocities refer to 33 ft. above ground.

Beaufort Notation and Symbols for Weather

b, blue sky (not more than a quarter covered with cloud).
bc, sky partly cloudy (one half covered).
c, generally cloudy.
d, drizzle. e, wet air. g, gloom.
f, fog, visibility 220–1100 yd.
F, thick fog, visibility less than 220 yd.
fs, fog over sea (coast station).
fg, fog on lower ground (inland station).
m, mist, visibility 1100–2200 yd.
h, hail. i, intermittent.
jp, precipitation within sight of station.
ks, storm of drifting snow.
k/s_o, slight storm of drifting snow (generally low).
K/S, heavy storm of drifting snow (generally low).
s_o/k, slight storm of drifting snow (generally high).
S/k, heavy storm of drifting snow (generally high).
KQ, line squall. l, lightning.
o, overcast sky. p, passing showers.
q, squalls. r, rain. s, snow. rs, sleet.
t, thunder. u, ugly, threatening sky.
v, unusual visibility. w, dew.
x, hoar frost. y, dry air.
z, dust haze; the turbid atmosphere of dry weather.
h(r), "hail" or "rain and hail."

Capital letters indicate intense; suffix o indicates slight; repetition of letters indicates continuity: thus: R, heavy rain; r_o, slight rain; rr, continuous rain.

With present weather is combined, whenever possible, the general character of the weather.

A "solidus" divides actual existing weather from preceding conditions thus:—bc/r, fair weather after rain;. —, has decreased; + has increased.

2. IMPORTANT TERMS

Before considering types of weather maps and their interpretation, it is well to note the meaning of certain terms used in connection with such maps.

BAROMETRIC PRESSURE.—It has long been known that the air has weight. Therefore it must press upon the earth, and the pressure at any point of the earth's surface is influenced by the quantity of air above. Pressure at the foot of a mountain is greater than at the top, but at sea-level pressure at different places varies, as well as at the same place at different times. Such variation is associated with changes of temperature, because the density of air is affected by temperature. Hence temperature readings find a place on weather maps.

Atmospheric pressure is measured by the barometer. The pressure of the atmosphere is the same as would be the pressure exerted by a layer of mercury as deep as the mercury column in the barometer is high. It is usual to give the pressure of the atmosphere in inches or millimetres of mercury, and such are termed barometric readings. The density of mercury can be found, and it is easy to convert this into units of weight per unit of area. The average pressure at sea-level is 29·9 in., which represents about 14·7 lb. per sq. in. Formerly, on weather maps barometric pressures were expressed in inches, but now they are indicated in " millibars," one thousand millibars being equivalent to 29·53 in. of mercury. Conversion of inches into millibars or *vice versa* is a matter of simple proportion, for instance, 950 millibars = 28·05 in.; 1,050 millibars = 31·01 in.

ISOBARS.—Isobars are lines of equal barometric pressure, being drawn through places where the pressure (reduced to sea-level equivalent) is the same. They can be compared with contours, the " vertical interval " generally being 4 millibars, which corresponds to about $\frac{1}{8}$ inch of mercury.

BAROMETRIC GRADIENT.—The barometric gradient is the rate of fall of barometric pressure measured at right angles to the isobars. The unit of barometric gradient is a fall of $\frac{1}{100}$ in. in 15 nautical miles. Thus, if isobars 30·1 and 30·3 are 20 nautical miles apart (measured at right angles to the isobars) the gradient is $\frac{20}{100}$ in. in 20 ml., or $\frac{15}{100}$ in. in 15 ml., that is, it will be 15. Where isobars are close together and the gradient is thus high, winds are strong; where isobars are far apart and the gradient is low, winds are light.

ISOTHERMS.—Isotherms, or lines of equal temperature, are drawn through places having the same temperature when reduced to sea-level. On British weather maps temperature is reckoned in degrees Fahrenheit, but the isotherms are not actually drawn, the temperature readings only being inserted on the site of each meteorological station. Isotherm maps are associated with climate rather than with weather.

ISOHYETS.—Isohyets, or lines of equal rainfall, are drawn through places having the same amount of rainfall for a given period: month, season, or year, as the case may be. It is obviously impossible to draw them with any accuracy on weather maps which usually indicate the weather for a period of twenty-four hours. On weather maps, a special symbol is used to show that rain is falling at a given station, and other symbols are used to indicate to what extent the sky is clouded. There are also symbols for snow, hail, fog, mist, and other meteorological phenomena.

ISALLOBARS.—These are lines drawn through places where the barometer has risen or fallen by the same amount during the preceding three hours. Inset maps showing isallobars may be given on weather maps, and are useful for comparing the barometric rise or fall at different places.

DEPRESSIONS AND ANTICYCLONES.—A depression (or cyclone) (Figs. 52, 57) is an area of low pressure surrounded by high pressure. An anticyclone (Fig. 48) is an area of high pressure surrounded by low. Weather reports to-day refer to "depressions" rather than "cyclones," the latter term being considered more suitable for certain tropical storms.

3. RAW MATERIAL OF THE WEATHER MAP

A weather map may represent conditions (*a*) at a given instant of time, *e.g.* the daily weather map of Britain or the U.S.A.; (*b*) average weather over a period, *e.g.* over a month or year. Maps of the latter type deal with climate rather than weather, climate being the sum total of average weather conditions. Weather may refer to the state of the sky, *e.g.* cloudiness, rain, snow, mist, fog, etc.; the temperature and humidity of the air; wind, its direction and strength; and, especially for aviation, visibility. Previous to the construction of a weather map, careful and systematic observations of most of these items are necessary. In connection with such maps, there is a type of observation, not of actual weather conditions, but important as a key to them, viz. barometric pressures.

It was in 1860 that the first official observations were dealt with by the Meteorological Office, which had been formed a few years previously. The first official weather maps were made in 1872. It was not until the latter part of the nineteenth century that results of observations were received from stations in Central Europe. At the beginning of the 1914-18 War, results of fairly full observations were received from the Azores, the continent of Europe, and ships at sea, and use was made of wireless telegraphy. The needs of aircraft, etc., made it necessary during the War to develop more thorough observations of the upper atmosphere, and, as a result, considerable progress was made in forecasting. Further advances were made in 1939-45 and for similar reasons.

The most important countries of Europe, with the U.S.A., maintain many observing stations, which at agreed hours in the 24, make observations, the times being fixed by international agreement. Results of these observations are reported by ordinary or wireless telegraphy to the central office in each country, from which they may be sent abroad.

At the fixed hour, the trained observer goes out, notes the state of sky, the amount and type of cloud, whether there is any precipitation, whether visibility is good or bad; also the direction and strength of the wind (unless there is a wind recorder); the temperature at the temperature screen. He examines the rain gauge, and measures the amount fallen; he reads the barometer or barograph. All these results are transmitted by code. At the internationally agreed hours, ships at sea take as many observations as possible, and transmit them by wireless, giving their position; these results are picked up by land stations and sent to the Central Office. Twice daily, the U.S.A. sends a wireless report of conditions in the U.S. and Canada. Here are the essentials for making a map, presuming it to be founded on periodical observations. These observations must be made and recorded scientifically, *i.e.* instruments must be accurate, observations must be made accurately and simultaneously. Regular and speedy transmission of news to the Central Office is necessary. Also, there must be uniformity in methods of observation.

4. THE POLAR FRONT THEORY

For an understanding of certain of the weather maps given on subsequent pages, it is necessary to grasp the *Polar Front Theory*, now generally used to explain the origin and character of depressions. The theory asserts that masses of relatively warm and cold air are brought into contact. These masses are

known as polar and equatorial air, from their source of origin. Polar air is cold and dry, equatorial air is warm and moist. These masses of air are held to flow in roughly parallel, but in opposite directions, respectively from N.E. to S.W. and S.W. to N.E. (Fig. 38). The line of separation is termed the **polar front.** The streams of warm and cold air do not always maintain the directions shown in Fig. 38. When a depression is forming a bulge of warm air develops towards the north, and the warm air pushes up into the cold, as shown in Fig. 39, where the broken line represents the approximate position of the polar front before this movement took place. At the forward boundary of this bulge, or **warm sector** as it is called, warm air is blowing against colder heavier air and gradually rising over it. At the rearward boundary of the warm sector heavier colder air begins to undercut the warm air and to lift it off the ground (Fig. 40). At the same time, the warm sector as a whole moves forward with the depression of which it forms a part, and rotates very slowly about the centre of its depression.

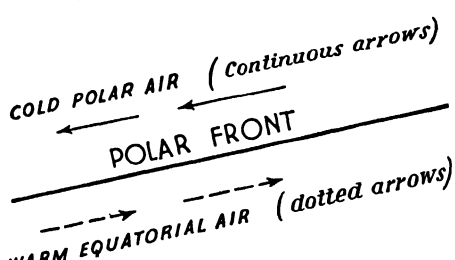


Fig. 38. Diagrammatic Representation of the Polar Front.
(Theoretical idea. Conditions are never stable.)

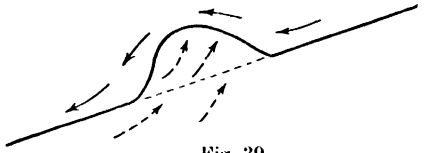


Fig. 39.

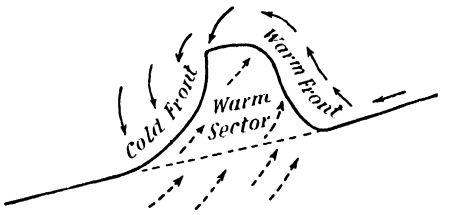


Fig. 40.

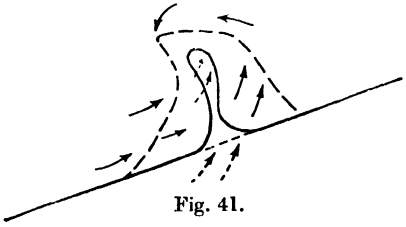


Fig. 41.

As the forward boundary of the warm sector reaches a given place the colder air in front of the warm sector is replaced at that place by warmer air. Hence the forward boundary of a warm sector is called a **warm front,** since its passage is accompanied by a rise in temperature. At the rearward boundary

of the warm sector, warm air is being replaced by colder air, and this boundary is called a **cold front.**

The cold front of a warm sector moves forward at a greater speed than the corresponding warm front, so that the cold front gradually overtakes the warm front and the warm sector decreases in size as more and more of the warm air is lifted right off the ground (Fig. 41). This occurs first at the tip of the warm sector. When all the warm air has been lifted off the ground the warm sector is said to be **occluded,** and the line along which the warm air left the ground is spoken of as an **occluded front** or more briefly as an **occlusion.**

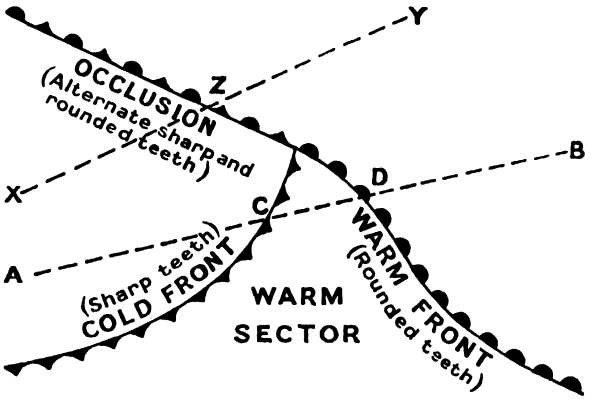


Fig. 42. Diagrammatic Representation of Fronts on a Weather Map. The lines AB and XY are the directions of the elevations shown in Figs. 43 and 44 respectively.

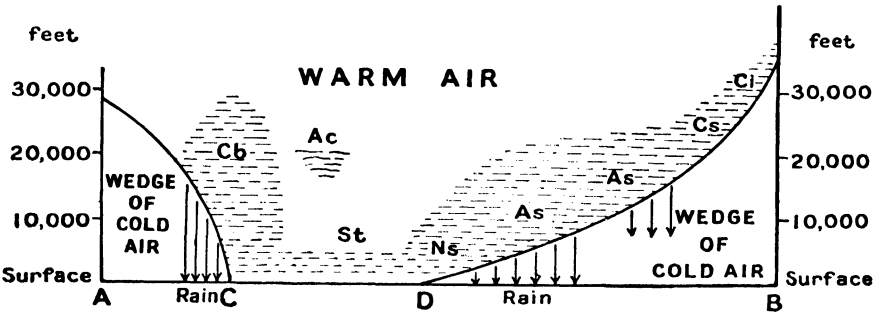


Fig. 43. Elevation along line AB in Fig. 42, showing cloud types in warm sector. Note that the vertical scale has been greatly exaggerated in proportion to the horizontal scale: DB may represent a distance of perhaps 500 or 600 miles.

Ci, cirrus; Cs, cirro-stratus; As, alto-stratus; Ns, nimbo-stratus; St, stratus; Ac, alto-cumulus; Cb, cumulo-nimbus.

The position of fronts is marked on weather maps by lines of rounded or pointed "teeth." Rounded teeth are used for warm fronts, pointed teeth for

cold fronts, and alternate rounded and pointed teeth for occlusions (Fig. 42). In each case the teeth point in the direction in which the front is moving.

As the warm air slides up over colder air at a warm front, the air cools and condensation of water vapour occurs, with the formation of clouds and, later, rain. Similarly clouds are formed at the cold front where warm air is being undercut by the colder air behind the front, but the upward movement of the warm air is not so smooth and regular here as at the warm front and so we tend to get shower and thunder clouds with a cold front, instead of the layer or sheet clouds associated with a warm front (Fig. 43).

5. WEATHER ASSOCIATED WITH DEPRESSIONS (Figs. 49, 52, 55, 57)

The isobars of a depression, sometimes known as a cyclone, a term, however, better reserved for a type of tropical storm, are roughly circular or oval, with isobars of lowest pressure inside. The size of depressions varies greatly; the height is relatively small. A depression is seldom stationary. In general, the movement of depressions in N.W. Europe is usually in an easterly direction. The direction of movement of a given depression on a weather map is usually the same as the direction of the isobars in the warm sector, and also is in the direction in which the fall of pressure is most rapid (as indicated by the barometric tendencies shown for the various reporting stations).

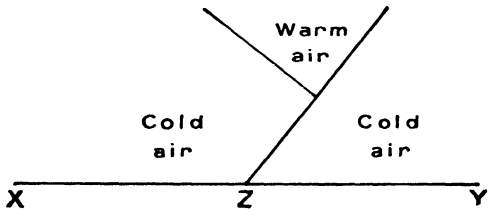


Fig. 44. Elevation along line XY in Fig. 42—an Occlusion.

The first sign of an approaching depression will be cirrus clouds, which give place to cirro-stratus, and these in turn to alto-stratus, followed by nimbo-stratus and rain. During this period the barometer falls steadily, but visibility is good until rain falls. Cirrus clouds are detached clouds of delicate and fibrous appearance, generally white; cirro-stratus is a thin, whitish veil which does not blur the outline of the sun or moon, but produces halos; alto-stratus resembles a fibrous veil, grey or bluish; nimbo-stratus is a low, amorphous layer, dark grey in colour.

When the warm front arrives, temperature will rise, wind will veer, *i.e.* change direction clockwise, and pressure continue to fall, but more slowly. Rain, at first intermittent and then continuous as the warm front approaches, ceases or becomes a drizzle after passage of the warm front. Visibility is poor, possibly with fog or mist. Cloud will be stratus, *i.e.* a uniform layer of cloud resembling fog but not resting on the ground, or alto-stratus. During passage of the warm sector temperature is usually fairly constant and there is drizzle rather than rain. During passage of the cold front temperature falls quickly, wind veers, and there may be squalls; there is heavy rain, perhaps with hail or thunder, pressure rises, and visibility is usually poor. Visibility rapidly becomes good or very good after passage of the cold front. In the cold air behind the cold front continuous rain soon stops, but there may be occasional rain showers, with less cloud. This is a general and necessarily an " ideal " description of a polar front depression, and individual depressions will, of course, vary in some details.

6. WEATHER ASSOCIATED WITH ANTICYCLONES (Figs. 48, 50, 53, 54, 56)

An anticyclone or " high " (*i.e.* high pressure area) is an area of high pressure surrounded by low. Isobars near the centre of an anticyclone are generally wide apart, and thus indicate light winds, and anywhere in the anticyclone the winds are rarely of more than moderate strength. In connection with anticyclones it is useful to consider lapse-rate in conjunction with stability and instability. Lapse-rate is the rate of fall of temperature with increasing height, and can be measured anywhere, *e.g.* we could speak of the average lapse-rate in the first fifty feet from the ground. A negative lapse-rate, *i.e.* temperature increasing with height, is called an inversion. This term is also sometimes used for the level at which the maximum temperature occurs. The average lapse-rate is 3·3° F. per 1,000 ft. Air having a low lapse-rate is relatively stable, and air with a high lapse-rate, *e.g.* polar air, is unstable and gives showers, etc. An inversion has important effect on weather, because it renders the air very stable, so that rising air cannot penetrate the inversion but is forced to spread out when it reaches the inversion layer. In anticyclones there is an inversion well above the surface. If the rising air contains cloud, the cloud will also spread out in sheet form. Under such conditions the very fine water droplets that form the clouds are unable to coalesce sufficiently to produce drops large enough to fall as rain. Hence we

understand why rain seldom falls in a well-marked anticyclone, although drizzle may occur, with dull overcast skies.

There are two types of anticyclone; both give quiet, fair weather, but one has little cloud, hence a heat wave in summer and a cold spell of severe weather in winter. Clear skies give (*a*) heat waves in summer because there is no "cloud blanket" to check free play of the sun's rays, and (*b*) cold spells in winter because there is no cloud to check loss of heat by radiation during the long winter nights. In middle latitudes anticyclones can be classed as cold or warm. The former occur when a current of cold air moves southward in the rear of a family of depressions, the greater density of this cold air causing increase of pressure. Highs of this type are essentially of maritime origin, as their association with depressions shows. They seldom last beyond a few days, but over the land the winter cooling of the earth's surface may prolong them. Warm anticyclones of middle latitudes may be (*a*) an extension from the subtropical high, sometimes known as the Azores High, or (*b*) a development from a cold anticyclone. A warm anticyclone of type (*a*) results in a spell of fine warm weather over the land in summer, but at sea causes fogs during spring and summer and fogs due to radiation over the land in winter.

7. OTHER PRESSURE SYSTEMS AND THEIR WEATHER CONDITIONS

THE SECONDARY DEPRESSION.—This is a low-pressure system contained in a bigger one. Secondaries vary in intensity from just a slight bend in the isobars to a system that contains closed isobars with steep gradients and well-developed winds. They form in any part of a depression, but develop most on the southern side. They cause increased wind on the side furthest from the main depression, and have their own wind circulation apart from that of the main one. The easterly winds on the north side are less strong than the westerly winds on the south side, and some of our strongest winds are associated with secondaries. This is because the centre of a primary depression is often north-west of Britain, so that we escape winds from the primary, but receive those of the secondary. The southerly gales in front, and the westerly gales on the south are strong and often do damage. The weather in a secondary is similar to that of a primary—warm and cold fronts, giving clouds and rain. Secondaries are the most common of depressions here; they often move anti-clockwise round a primary (Fig. 46).

A TROUGH OF LOW PRESSURE, formerly known as a " V-shaped depression," is associated with the warm or cold front of a depression. If it is of the warm front, rain may be persistent before the depression passes, and may give place to mild, cloudy weather behind. If it is of the cold front type, it will cause clearing-showers with bright skies and cooler weather. Such troughs are sometimes found without an associated front (in which case there is no discontinuity in the direction of the isobars, such as occurs at a front). A deterioration of weather is usually found with non-frontal troughs.

A RIDGE, formerly known as a " wedge," is a region of high pressure where the isobars take the form of an inverted V. Pressure is high within the V; a ridge usually projects north from a high-pressure area, and has lows to the east and west. It generally moves east with depressions and wears away. Ridges are usually regions of fine weather (Fig. 47).

THE COL.—A col is a central region between two highs and two lows. In a col, conditions are neither cyclonic nor anticyclonic, but it is a region of calm. In winter, weather is calm and foggy; in summer, if the sky is clear, there may be thunderstorms. It is a kind of " neutral " region (Fig. 51).

8. FORECASTING

Modern weather forecasting is primarily based on (1) the study of air masses, particularly their relation to one another; and (2) their physical properties, especially temperature, humidity, and pressure. Air masses are classified according to their probable origin, *e.g.* air of what is broadly termed (*a*) polar, (*b*) equatorial origin. Each of these cold or warm air masses may be subdivided into (1) maritime or (2) continental air, according to origin. The origin of these air masses is inferred from their properties—temperature, dew point, lapse-rate, etc. The last named is found from upper air observation by aircraft, or radio sondes. It can also sometimes be inferred from surface phenomena, *e.g.* a showery type of weather is associated with polar air, unstable owing to its high lapse-rate.

Once the fronts have been identified on the map the isobars are sketched in from the pressure readings and wind directions. Surface winds blow roughly parallel to the isobars but somewhat deflected towards the lower pressure. The amount of deflection, or "backing," is smaller the stronger the wind. Strong winds occur when the barometric gradient is steep, *i.e.* when the isobars are close

together. At inland stations wind direction is sometimes rather variable, especially with light winds, owing to differences in exposure of the observing stations. Since the passage of a well-marked front is accompanied by a sudden veer of the wind, isobars show a discontinuity in direction as they cross a front, unless this is stationary. Wind direction is usually the same throughout a warm sector, and hence in such cases the isobars in the warm sector are shown as parallel straight lines.

The forecaster will have to estimate the direction and rate of movement of each front. When this has been done, he is in a position to judge when the conditions associated with these fronts may be expected to reach the area for which he is forecasting. Such a forecast as "Rain spreading eastwards across area" will have been based on the identification of a warm front or occlusion approaching the area from the west. The speed at which the front is moving will have been estimated from the distance it has travelled between successive charts (which in British forecast offices are drawn every three hours) or from the speed of the upper winds.

Very detailed and accurate forecasts over wide areas are possible for a few hours ahead and are of great value for aviation purposes, but in Western European areas the forecasting of conditions for more than 24 hours ahead usually involves an appreciable element of doubt. To understand why this is so, let us consider a particular case. Let us suppose that the forecaster has identified a secondary depression out in the Atlantic which, on the basis of the necessarily somewhat scanty reports from such an area, he estimates to be travelling towards the mouth of the English Channel at, say, 35 m.p.h. (speeds of 50-60 m.p.h. are by no means rare). In 24 hours this depression will have travelled nearly 1,000 miles. The centre of the depression may now be moving across northern France, or up the Channel, or across southern England, or the depression may have turned northwards and be moving up the Irish Sea. The forecaster is aware of these possibilities and of the very different weather they would bring to, say, southern England, but the information at his disposal when he has to issue his forecast rarely permits him to do more than select the most probable of the various possibilities. In special circumstances, more particularly during anticyclonic weather, it is possible to issue satisfactory forecasts for two or three days ahead.

The following maps, with the notes on them, illustrating typical weather conditions, are adapted from *The Weather Map*, by kind permission of the Director of the Meteorological Office and the Controller, H.M. Stationery Office. Acknowledgement is also made to *Meteorology for Aviators* by Dr R. C. Sutcliffe and to *Weather Study* by Professor Sir David Brunt.

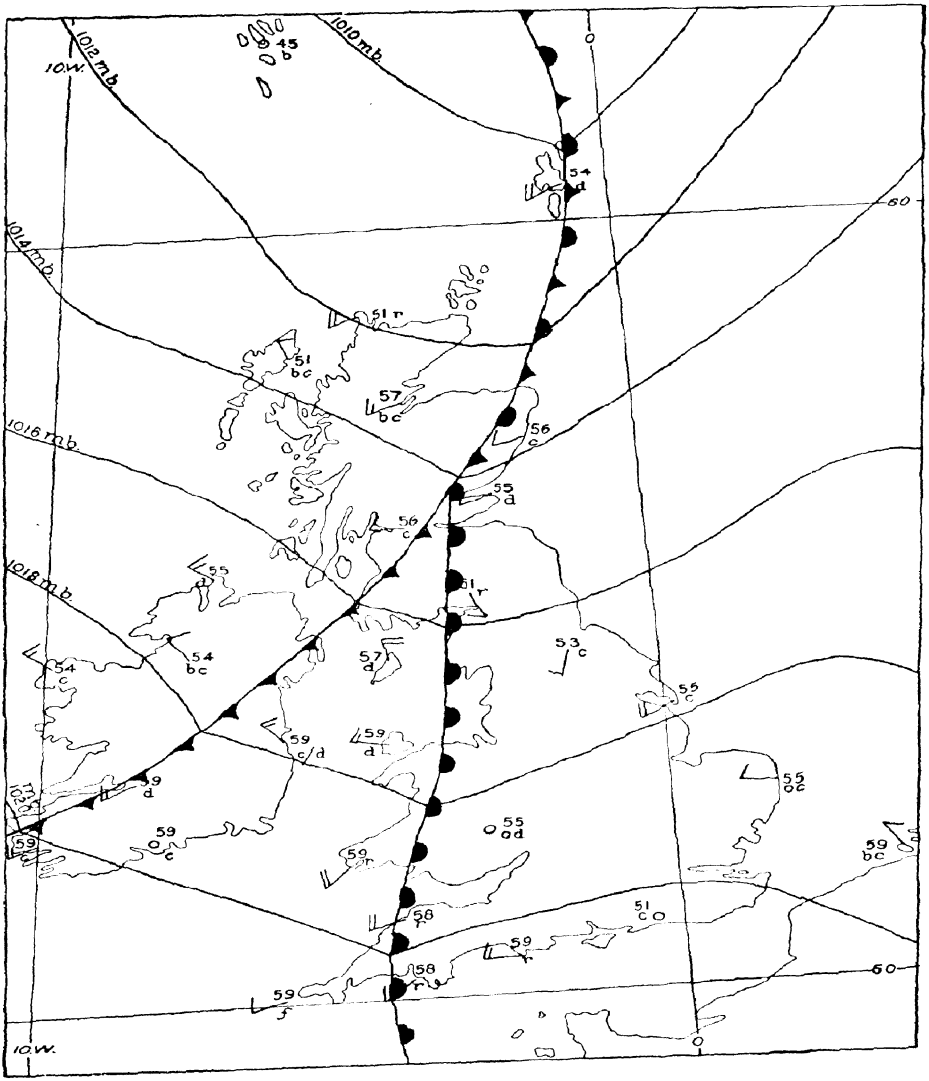


Fig. 45.

22nd August. A weak frontal trough of low pressure is crossing the British Isles. A belt of rain or drizzle with very low cloud and hill fog across South and East Scotland, North England, Wales and South-West England, will move steadily south-east. Behind this rain belt weather will become showery with bright intervals. It will be close at first becoming cooler.

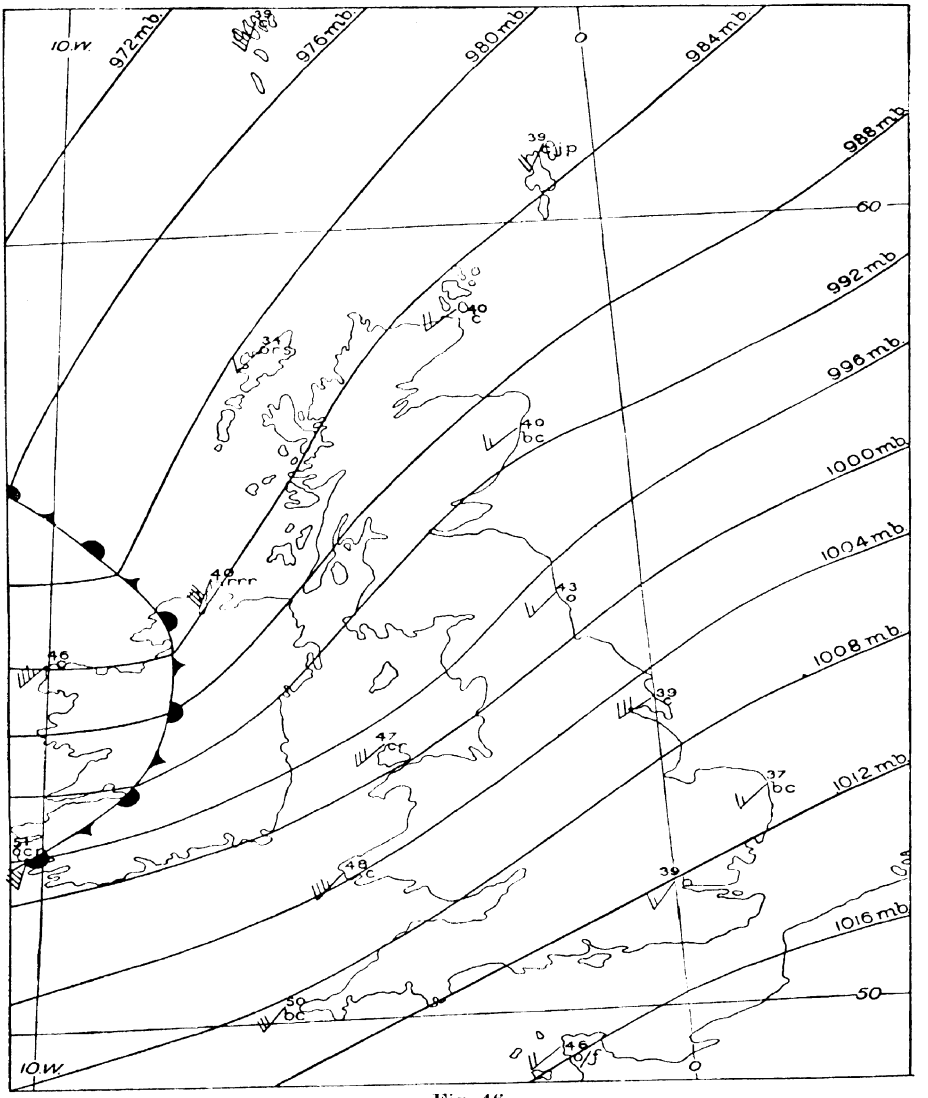


Fig. 46.

10th January. An intense secondary depression off the Hebrides will move rapidly north-eastwards, while the primary off Southern Iceland is tending to move a little south-east. Weather will continue stormy and unsettled and gales will be rather severe to-day in most northern districts. Further outlook: Stormy and unsettled but considerable bright periods in the south and east of England. Snow showers on high ground in the north.

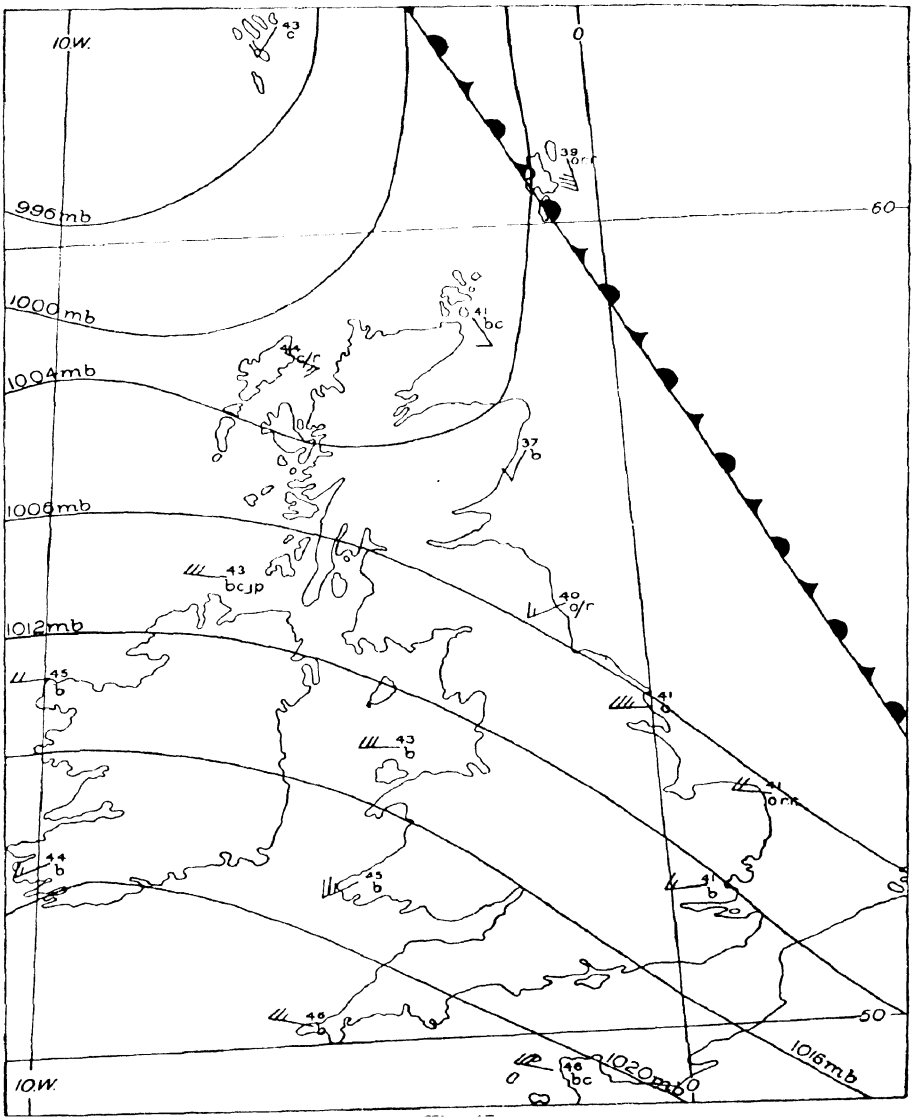


Fig. 47.

19th January. A ridge of high pressure crossing the British Isles will give a short fine interval, but a deep depression on the Atlantic will soon extend its influence over the British Isles.

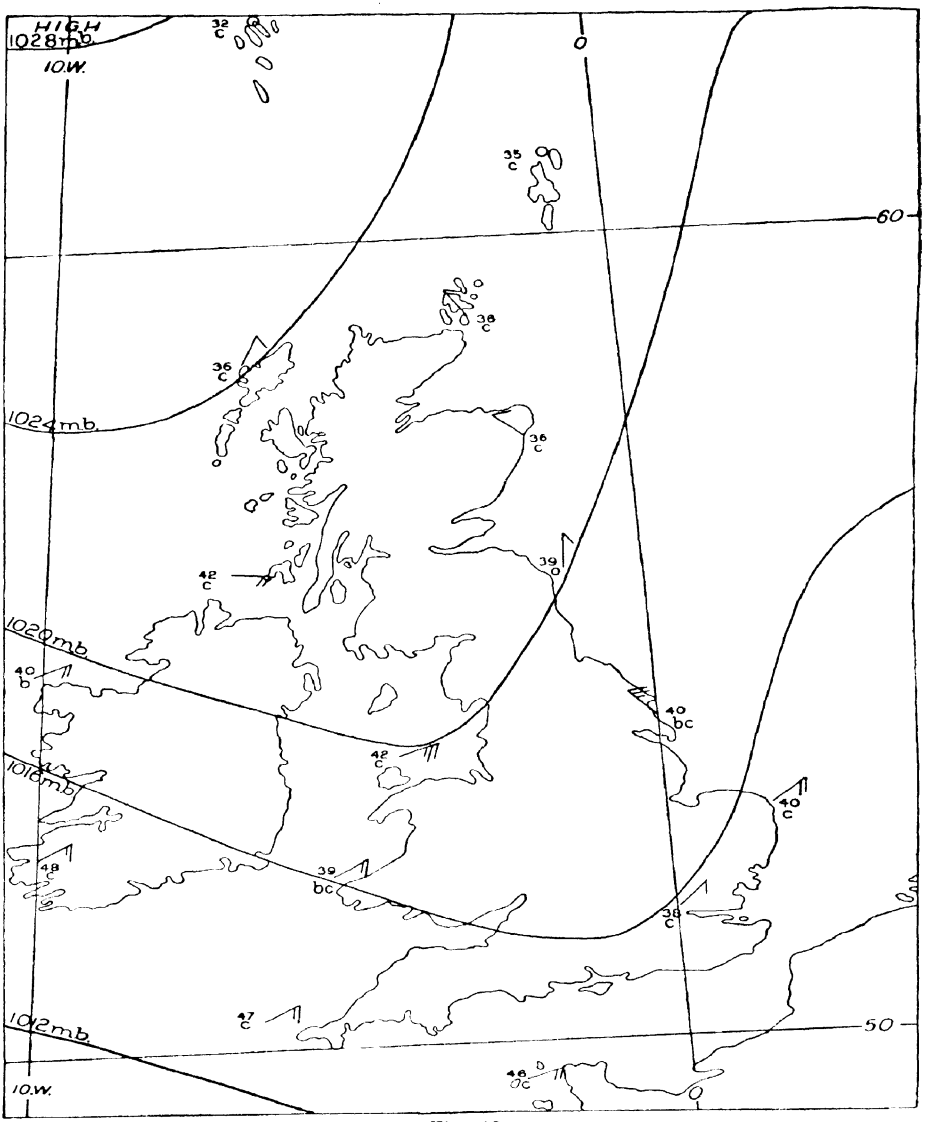


Fig. 48.

8th March. A large anticyclone over Iceland has extended its influence over the British Isles. Winds will be north-easterly and weather mainly cloudy and cold with local showers of rain or sleet, chiefly near the east coast.

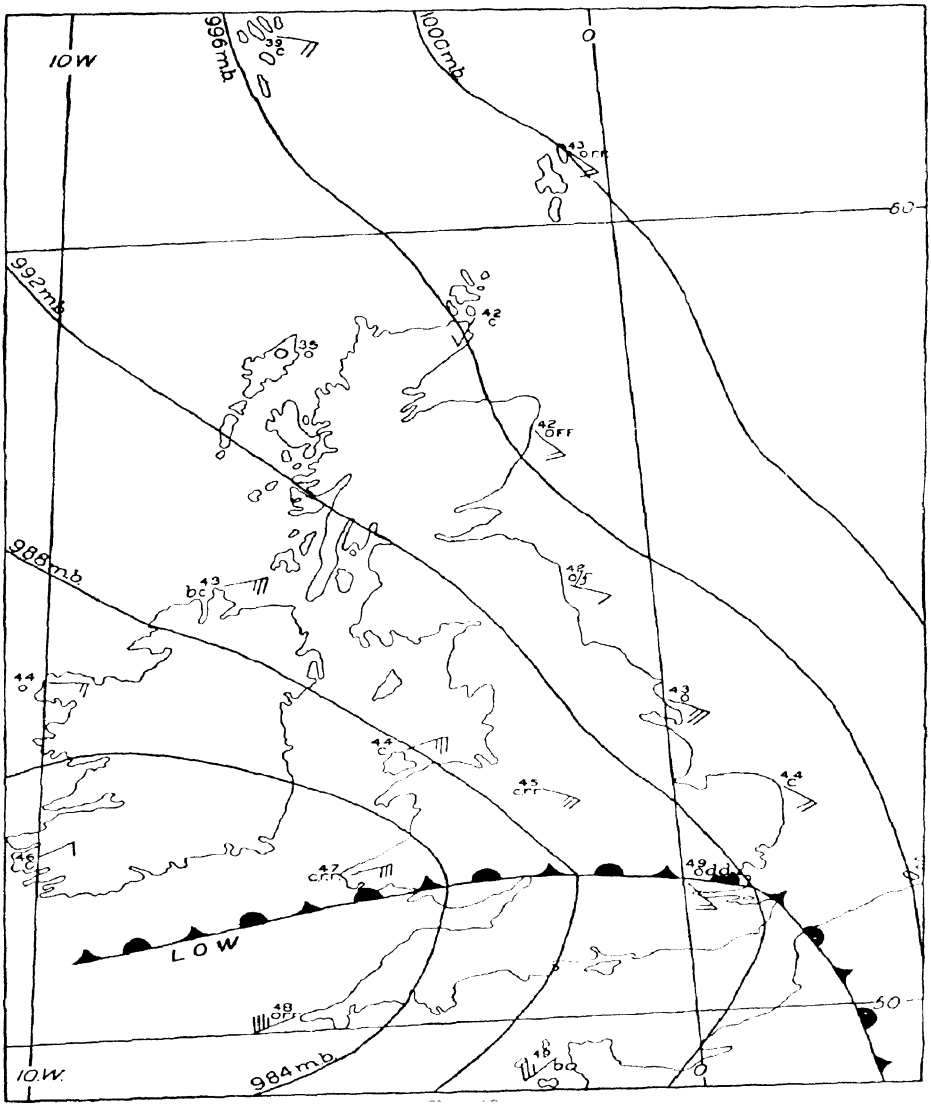


Fig. 49.

23rd March. A deep depression centred north of Scilly is moving slowly north-east and filling up. A rain area now over Southern England will move northwards followed by showers and bright intervals.

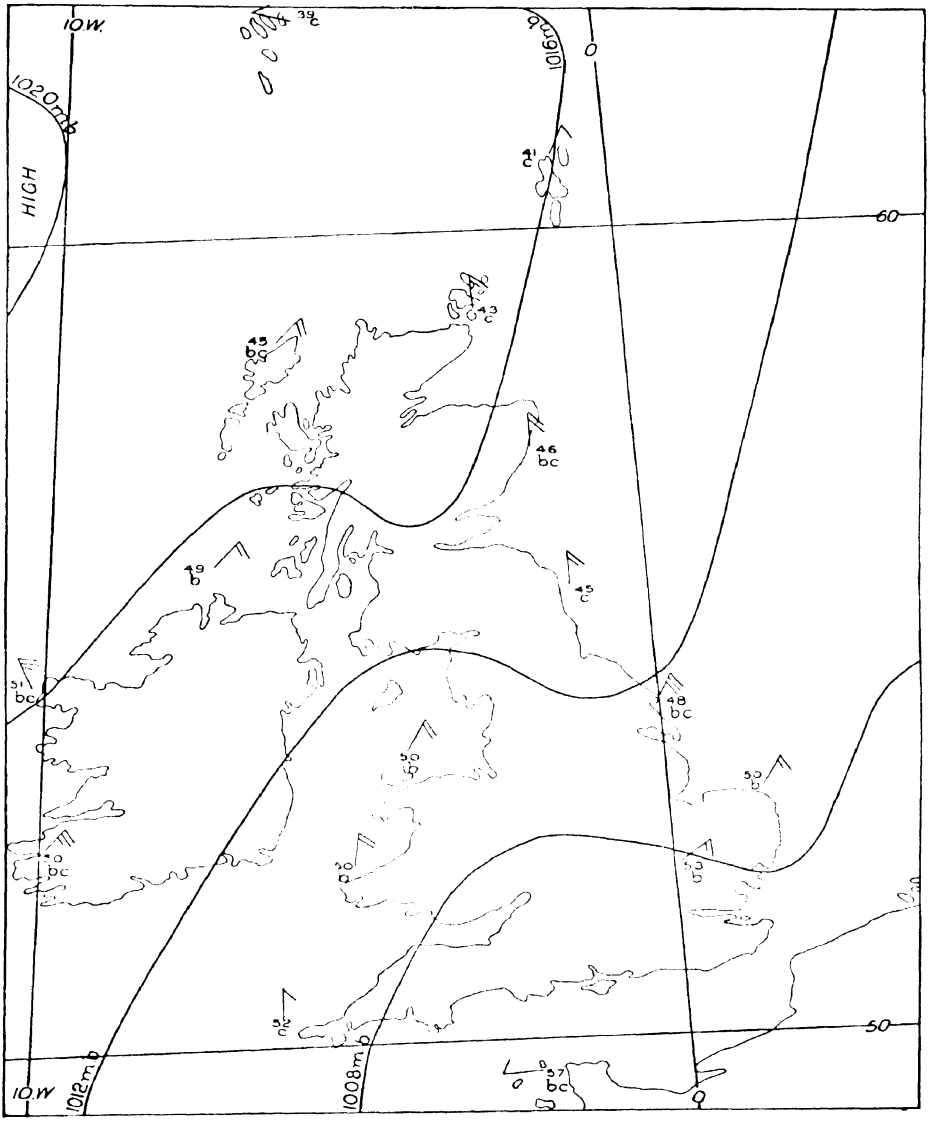


Fig. 50.

7th May. An anticyclone is centred off the Hebrides. Winds will be from a northerly point, and the weather will be mainly fair. Temperature will be considerably lower than of late, with ground frost in many places by night.

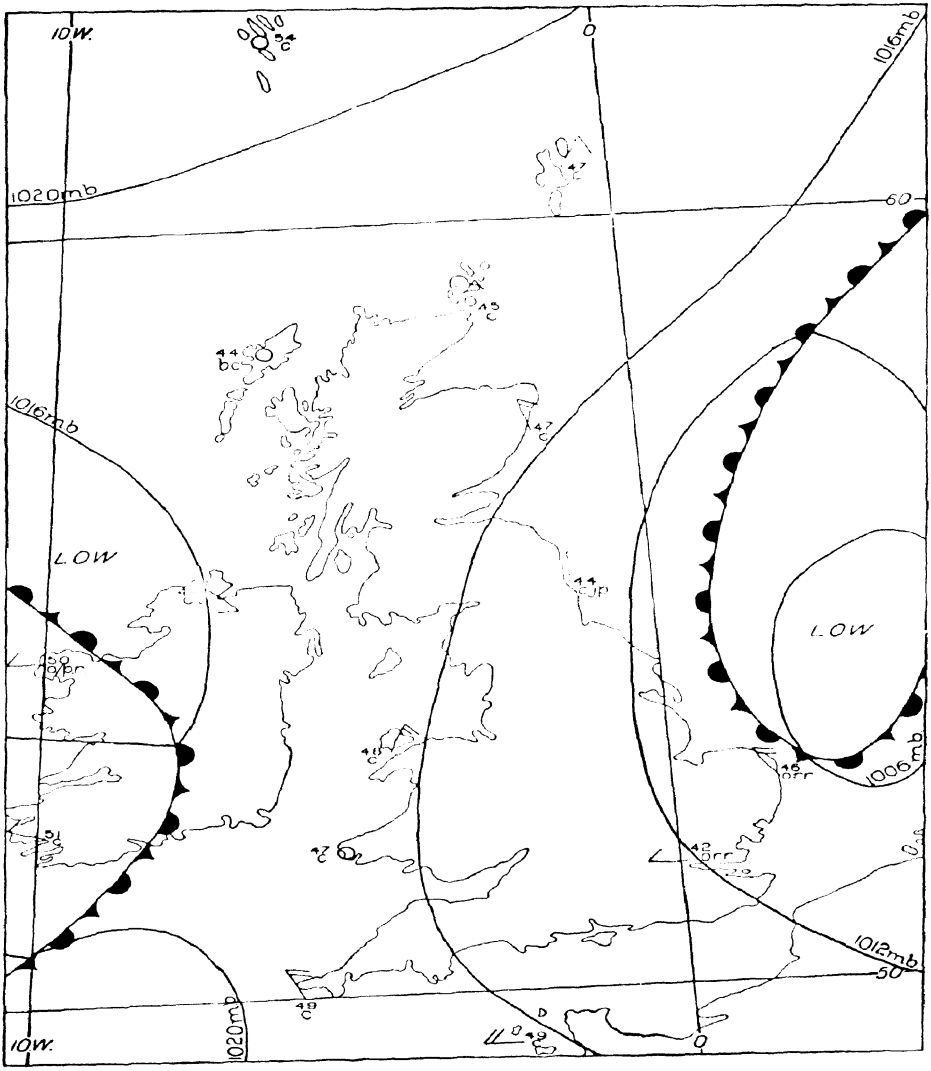


Fig. 51.

23rd May. A depression off the Irish coast is moving slowly south-eastward whilst another persists over the southern North Sea. Unsettled weather will continue with rain or showers in most districts except the extreme north of Scotland, but the temperature will be somewhat higher than of late. Further outlook: Unsettled.

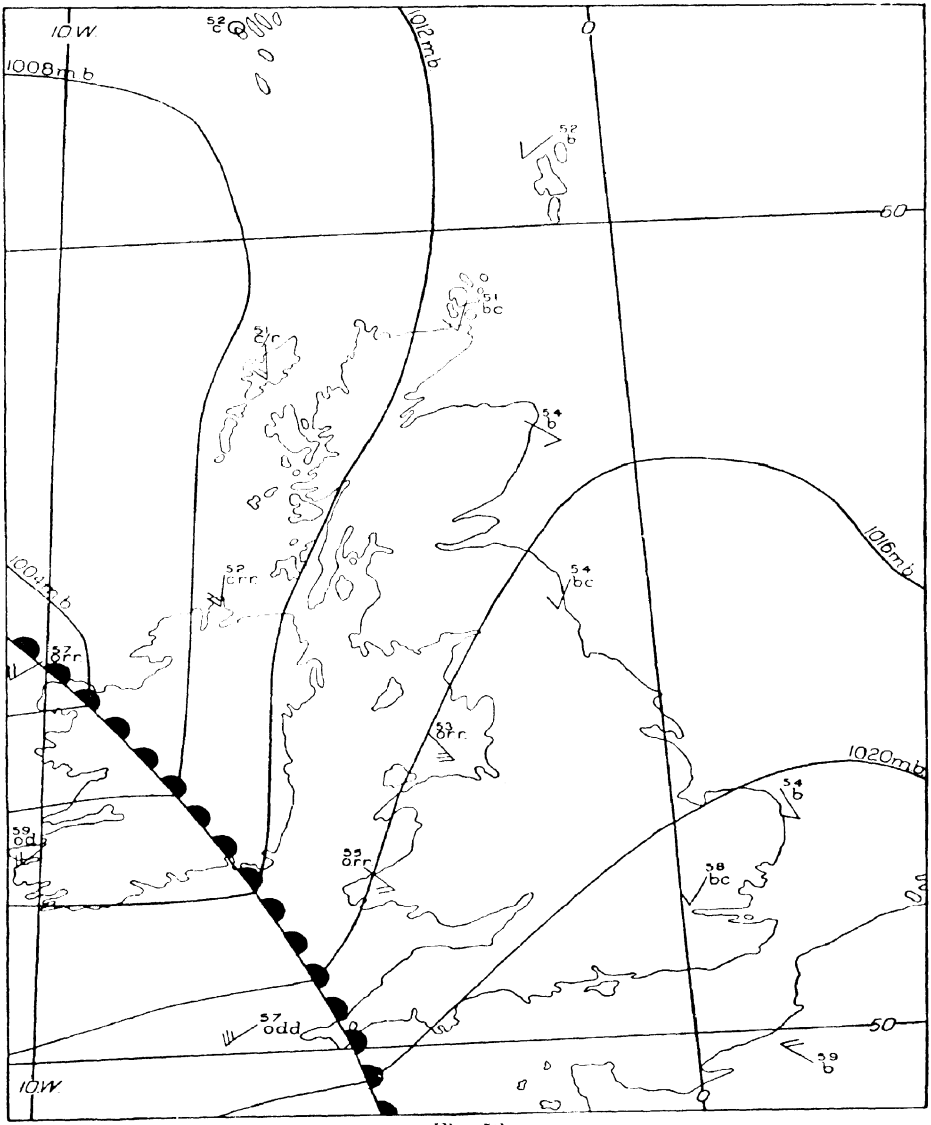


Fig. 52.

21st June. A depression off North-West Ireland is moving north-eastwards. Winds will be S. to S.W. and rain will occur generally, although in Southern England amounts will not be large. Further outlook: Unsettled.

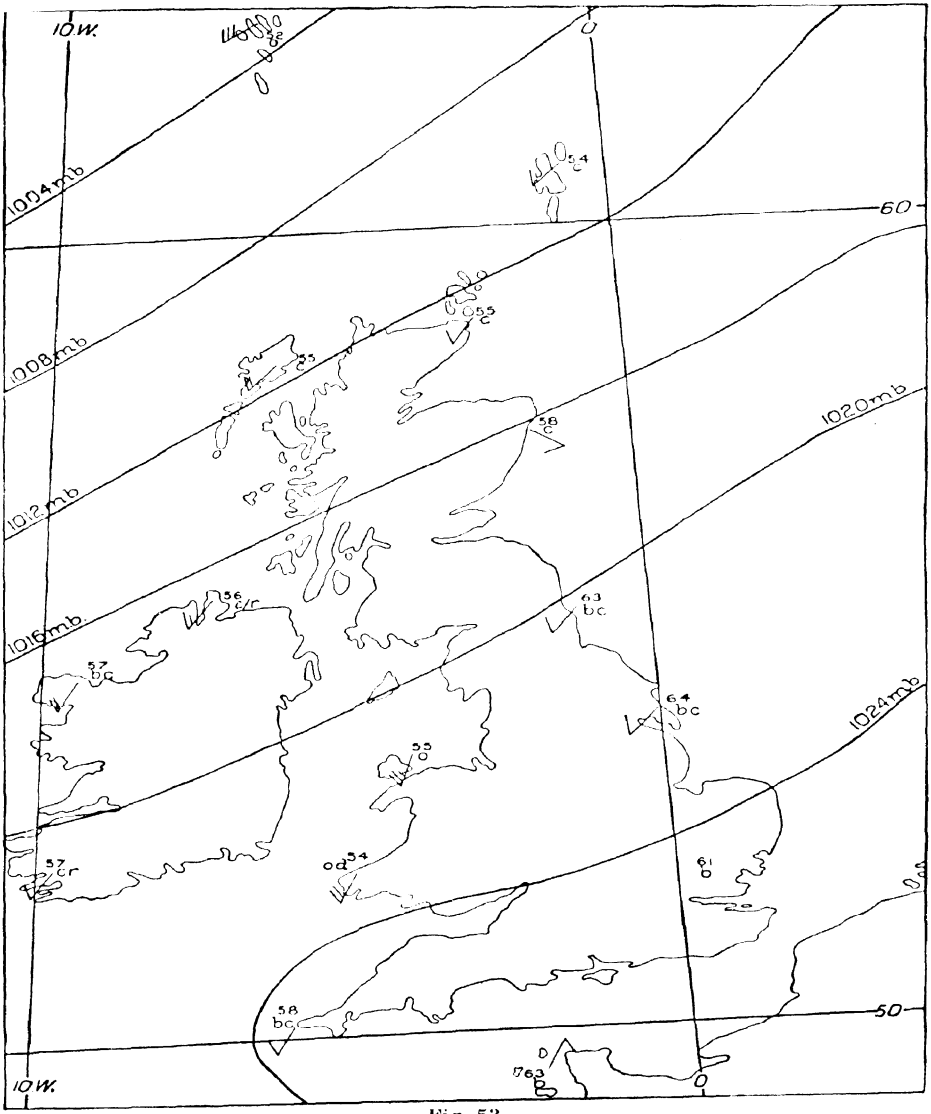


Fig. 53.

12th July. A belt of high pressure extends from beyond the Azores across France to Central Europe. Over most of England mainly fine and very warm weather will continue while in the northern and western parts of the British Isles there will be cloudy periods with occasional local drizzle. Further outlook: Similar.

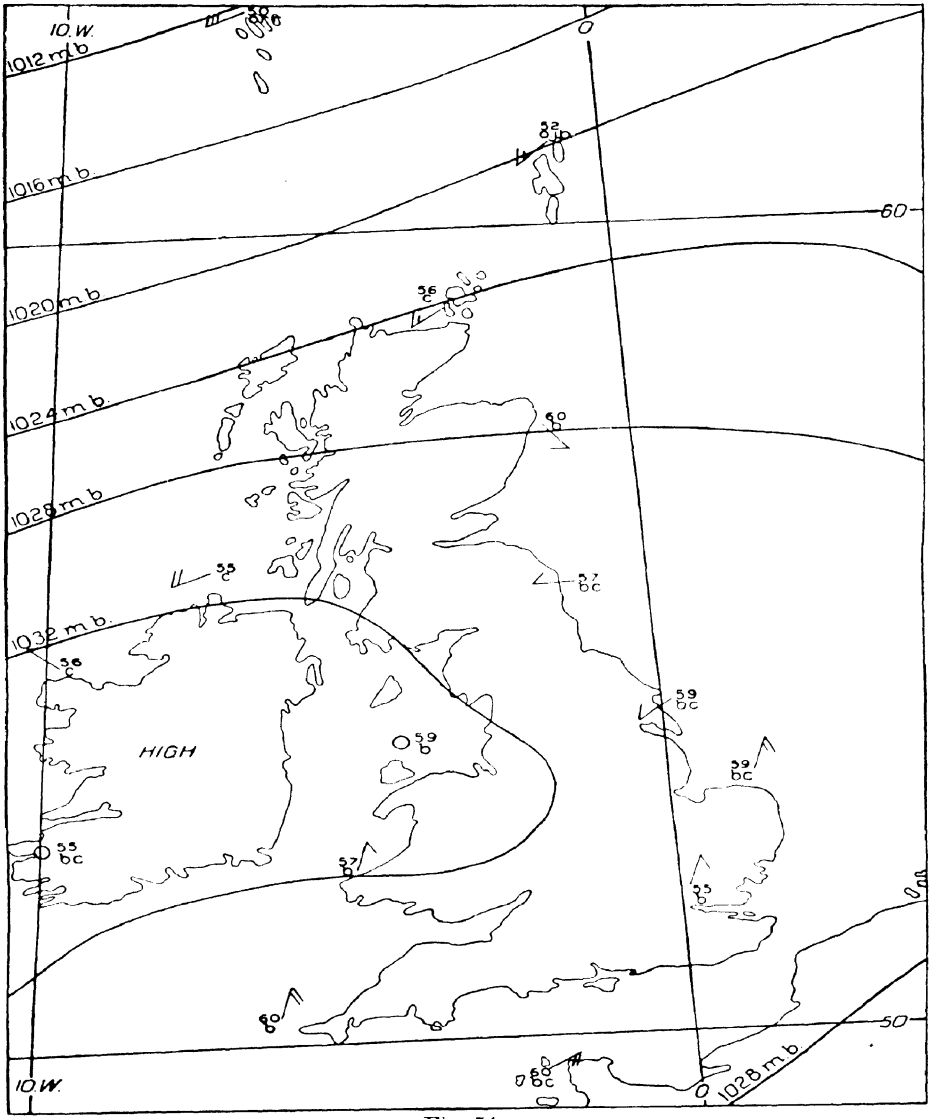


Fig. 54.

17th July. A large anticyclone covers Ireland, England and the southern North Sea. Fine weather will continue over most of the British Isles and probably last for four or five days. Temperatures will tend to rise again.

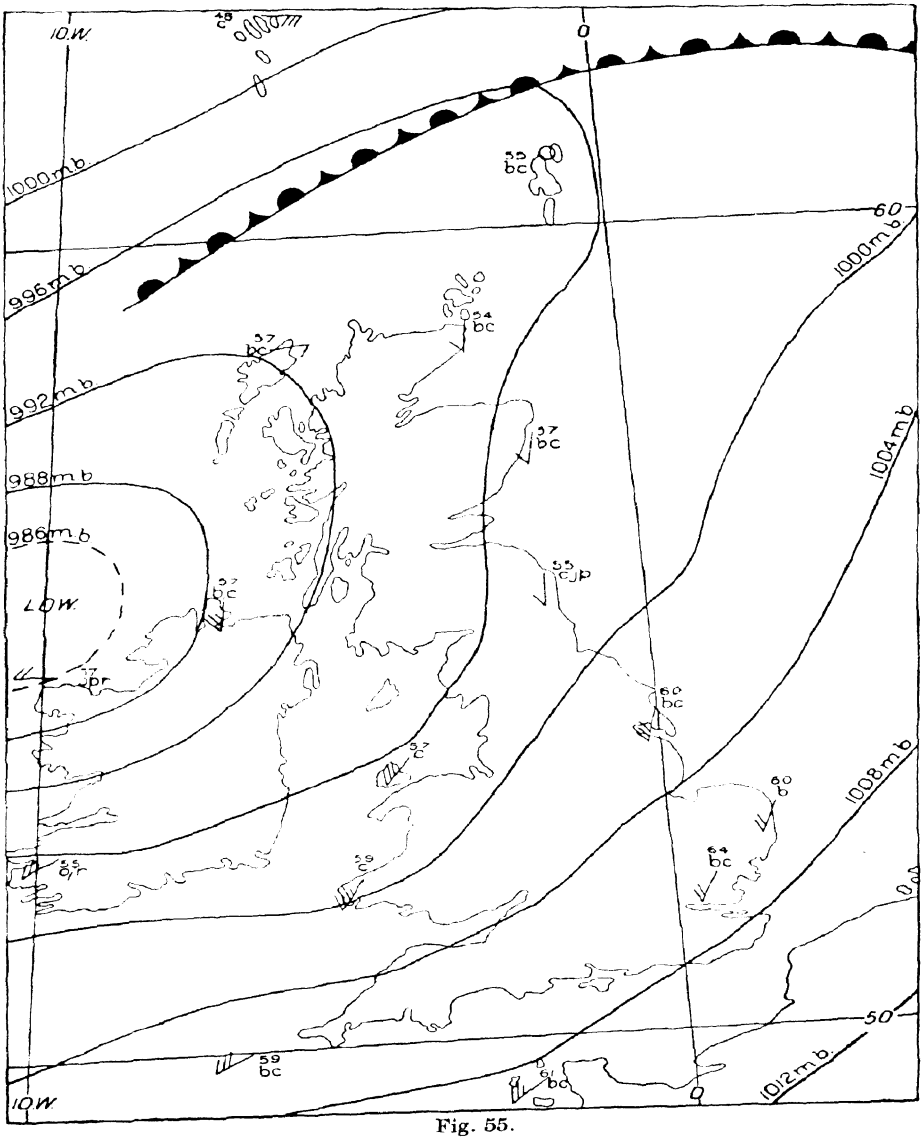


Fig. 55.

13th August. A deep depression off North-West Ireland remains stationary. Weather will be showery with bright intervals and local thunder. Further outlook: Showery weather for three or four days.

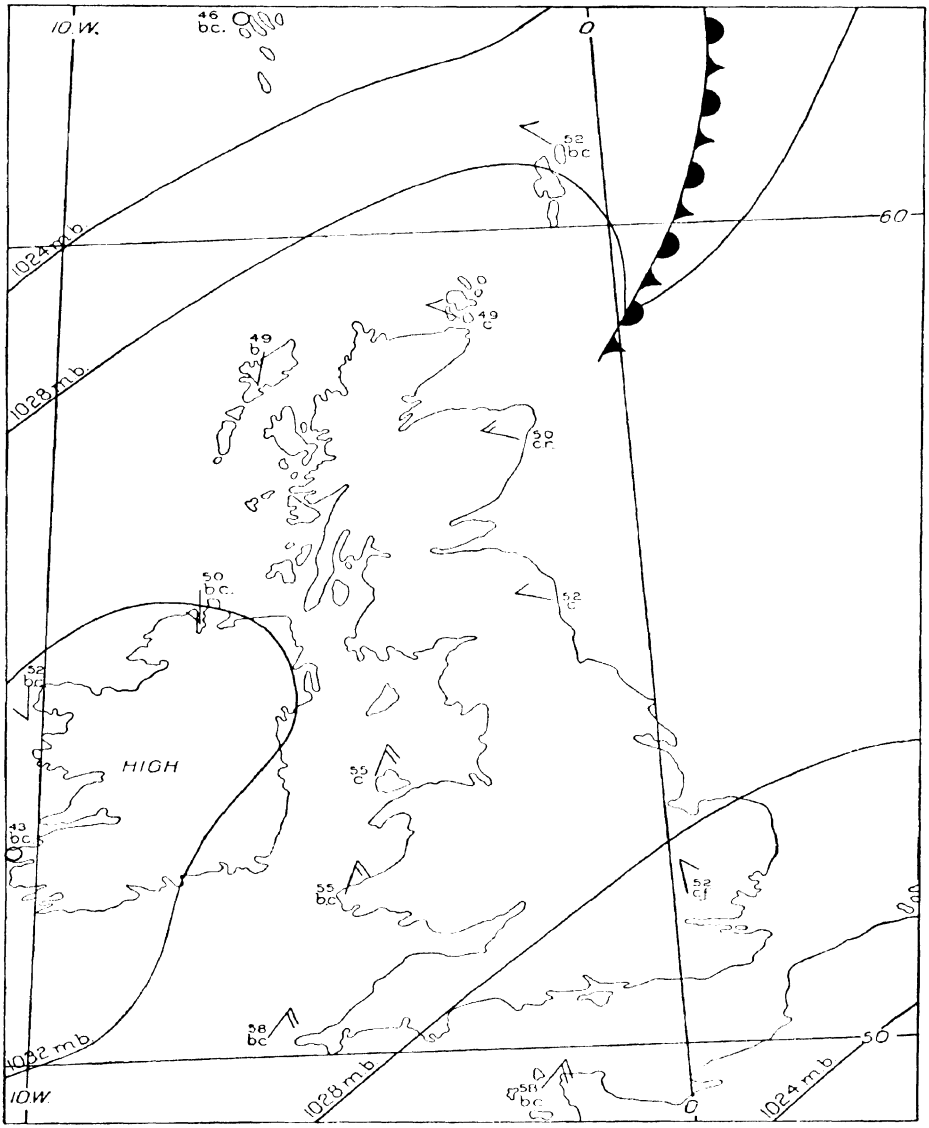


Fig. 56.

10th September. Anticyclones are centred over Scandinavia and Ireland. Quiet and mainly fair weather will continue with rather high day temperatures and at night slight ground frost locally.

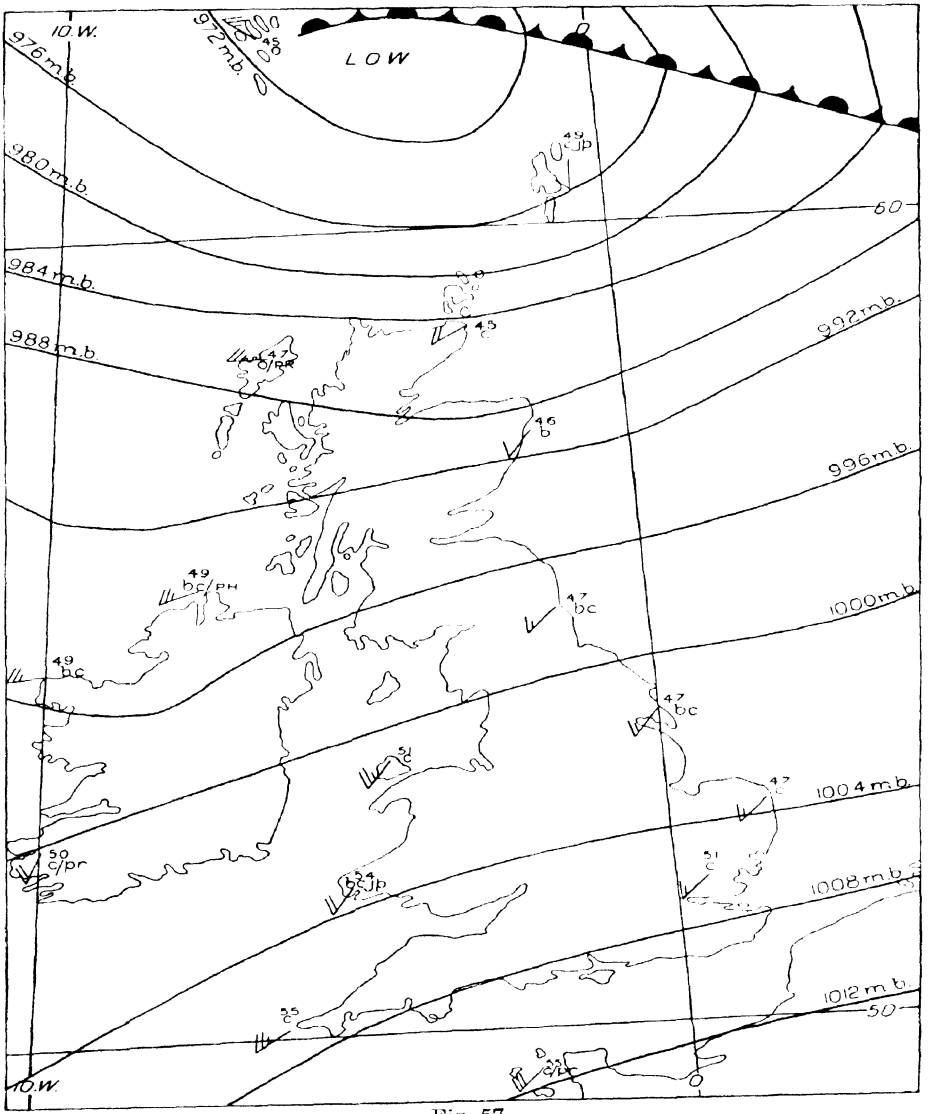


Fig. 57.

19th October. A further depression off Western Ireland is likely to move rapidly eastwards and cause mild unsettled conditions to spread from the west bringing further rain and freshening winds from a southerly point to all districts. Further outlook: Showers with bright intervals; temperature becoming lower.

CHAPTER X

SOME POINTS ABOUT CLIMATE MAPS

1. THE DIFFERENCE BETWEEN CLIMATE AND WEATHER MAPS

There is considerable difference between climate and weather maps. The weather map is essentially composite, most aspects of weather being shown on one map, whereas the climate map is more specialised, being, as a rule, used for only one main aspect.

Isobars are the most prominent features on the weather map, but no *lines* are used for temperature and rainfall. Temperatures are shown by numbers near the observing station, and are similar to spot heights on a contoured map. Rainfall and degree of cloudiness are indicated by symbols, and there are various symbols and letters for other aspects of weather. (See page 95.) Thus, though a maximum of information is given on one weather map, it is not overcrowded as would be the case if isotherms and isohyets were used. Too few observations would be available for the latter, and quantity of rainfall is essentially a subject for averages, so on the weather map it is sufficient to indicate that rain was falling at individual stations.

Separate climate maps are generally used to show temperature, pressure, and rainfall conditions, using isotherms (see page 98), isobars (see page 97), and isohyets (see page 98) respectively. The isotherms are given on a separate map, because to include isobars with isotherms would lead to confusion, though sometimes study of certain isotherms may help understanding of the isobars. Low temperature is often a clue to high pressure, and high temperature to low pressure. It is better to study jointly separate isotherm, isobar, and rainfall maps drawn on the same scale and projection than to crowd too much on one map. If maps drawn according to the same scale and the same projection are used, comparison and correlation of the various elements of climate will be easy. Arrows showing broadly the direction of the chief planetary winds can be combined with isobars, and would not be intelligible without the latter.

2. TYPES OF CLIMATE MAPS

Isobar, isotherm, and rainfall maps are constructed on the same principle as contour maps. The method is simple as long as observations from a sufficient number of stations are given. In rainfall maps, after the isohyets are drawn, shading or colour layering is often used between the lines. This is logical, as rainfall gives a concrete quantitative conception impossible in the case of temperature and pressure. The latter merely indicates the behaviour of mercury in a glass tube, whereas rainfall is a tangible thing. The colour, generally various tints of blue, indicates, according to the yearly average, that, say, between 60 and 80, or over 80 in. of rain have fallen in a specified region. The same thing could be read from the isohyets alone, but shading emphasises the difference, and the darker shading enables us to identify the districts of greatest rainfall.

Relief has considerable influence upon rainfall (see page 125), and to understand the rainfall map easily it is desirable at the same time to refer to a relief map. Altitude affects temperature and pressure, so before temperature and pressure maps are made, the statistics are " reduced to sea-level " in order that the resulting isotherms and isobars may be less complicated.

3. REDUCTION OF DATA TO SEA-LEVEL EQUIVALENT

Reduction to sea-level means that certain adjustments are made to cause the figures to be as nearly as possible what they would be if the places of observation were actually at sea-level. Rate of fall of temperature with increase of height (known as **temperature gradient**), varies from time to time and in different places. The average of many observations has shown that in round figures 300 ft. may represent the ascent producing a drop of 1° F. For short distances, as we go up, for instance in certain Swiss valleys, there may be *increase* of temperature, known as **temperature inversion**, but such a possibility can be ignored in making temperature maps.

Isotherms reduced to sea-level give little information about actual temperature conditions, except on lowlands or relatively low uplands. In Tibet and the high lands of central Asia, which are 15,000 or more feet above sea-level, they give quite a false impression, Tibet in July apparently having a higher temperature than the plains of Northern India, which is quite contrary to the real facts. However, if the isotherms were drawn from unreduced temperatures, readings from many more stations would be necessary, especially in regions of diversified

relief. There would be a very erratic temperature gradient unless so many isotherms were drawn that the map would be overcrowded. By an erratic temperature gradient we mean unequal intervals between isotherms.

Isobars reduced to sea-level may give a generalised impression not in accordance with actual conditions, especially in very high land. A station at sea-level may show the reading of 30 in.; another station on a mountain not very far away may show, say, 25 in. If these readings were plotted directly on the chart, the result would be a big gradient necessitating very crowded isobars, and we should expect great gales where possibly they do not occur. Hence to obtain comparable figures we must reduce readings to the same standard, and sea-level equivalent gives such a standard.

4. INSOLATION AND TEMPERATURE

The sun is the chief factor in the control of climate, as it directly affects temperature, which is the most important element of climate, because of its influence on pressure, winds, and rainfall. The distribution of temperature over the surface of the globe, the diurnal and seasonal changes of temperature, are influenced by variations in the duration and intensity of sunshine. The intensity and duration of sunshine mainly depend upon (1) the angle at which the sun's rays strike the earth; (2) the length of day. Both (1) and (2) depend upon latitude, and if the sun alone were concerned, all places on the same parallel of latitude would experience the same temperature. Various factors, however, disturb this uniformity, *e.g.* distribution of land and water, mountain barriers, prevailing winds, and ocean currents.

The temperature of a place is represented by the difference between the quantity of heat received by the earth from the sun (**insolation**) and the amount lost by the earth through **radiation.**

The more direct the angle at which the sun's rays strike the earth, that is, the nearer it approaches a right angle, the greater will be the insolation. The angle varies according to the latitude of a place, and at the same place it may vary according to season. In England, at London, at the summer solstice (June 21st) the sun's rays strike the earth at an angle rather more than two-thirds = eight-twelfths of a right angle, while at the winter solstice (December 21st) the angle is only $\frac{1}{4}$, *i.e.* three-twelfths of a right angle. Thus in June the insolation is much more than it is in December.

The longer the day, the greater the insolation, so that the length of the polar day compensates for the acute angle at which the sun's rays strike the earth in polar regions.

5. BENDING OF ISOTHERMS

The distribution of land and water influences the course of isotherms. Owing to its higher specific heat, *i.e.* its slower heating and cooling capacity, water will be cooler than land in summer and warmer in winter. This accounts for the curious bending towards the equator and the poles of isotherms drawn on the sea. If they bend towards the pole, as off Western Europe in winter, we realise that the sea is then warmer than the land, for, as it were, a tongue of warmth over the sea is pushed towards the pole. Realisation of this fact is a great help in reading isotherm maps. Poleward bend of winter isotherms, especially 32° F., over the North Sea and adjoining Atlantic Ocean is also due to the warm Atlantic Drift which tends to heat the air blowing towards Europe as south-west winds.

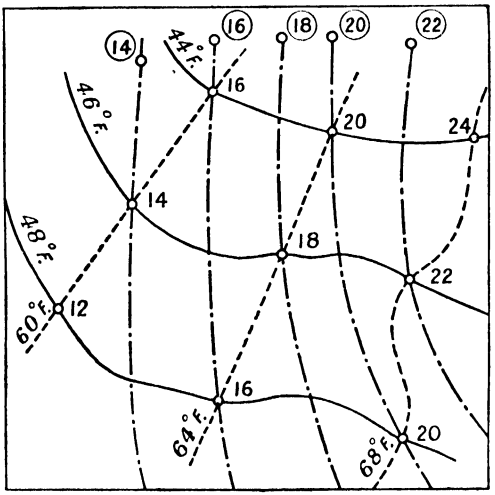


Fig. 58.
January isotherms ——— July isotherms - - - - -
Range lines –.–.–.–.–.

6. RANGE MAPS

Temperature maps are usually drawn with isotherms showing the mean of actual temperature observations for a single month or for the whole year, but there is another type of temperature map known as the **range map.** (See Fig. 58.)

Range is really the difference between the highest and the lowest temperatures ever experienced at a place. This is the absolute range of temperature, but it cannot easily be shown on a map, because such maximum and minimum temperatures vary from year to year. The average of such maxima and minima for a period of years is known as the mean annual **extreme** range, but a better way

is to take the difference between the average temperatures for the hottest and coldest months. This difference is often called the mean annual range.

In a fairly large area the hottest or the coldest month may not be the same. The coldest month at one station may be January, at another February; at these stations the hottest month may be July and August respectively. However, the range can be ascertained by taking the difference between January and July in the one case and between February and August in the other. In such a case the range maps are made by plotting at each station the ranges thus ascertained, and then proceeding as for isotherms or contours.

There is another and more graphic way of constructing range maps. Take, drawn on the same scale, isotherm maps for the coldest and the hottest month. On one of these maps trace the isotherms from the other. Where one isotherm (coldest month) cuts another (hottest month) find the difference between their values, and insert this difference, like a spot height, at the point of intersection. Such differences are range values, and the range lines can then be drawn like contours. No range-line must cross an isotherm except at intersections, but range-lines must cross both isotherms at the intersection.

In practice, it is well to draw the cold month isotherms in pencil, those of the hot month with a lighter black ink line. Range lines can be drawn with coloured pencil or red ink, and will thus stand out boldly.

7. RELATION BETWEEN ALTITUDE AND PRESSURE

Barometric readings denoting pressure of the atmosphere are always lower on the top (less dense air) than at the bottom (denser air) of a mountain. Near sea-level a layer of air 9 ft. thick is approximately equal in weight to a layer of mercury $\frac{1}{100}$ in. thick. Hence for every 9 ft. the barometer is raised, the reading will be $\frac{1}{100}$ in. less. If air were at all times and in every place of the same density, the height of any mountain would be obtained by reading the barometer at the bottom and at the top reckoning the mean as hundredths of an inch and multiplying by 9. However, the density of air is affected by both altitude and temperature. Tables are given containing what are known as " factors " for certain mean pressures and mean temperatures, and these factors are used in the way that 9 would be used as suggested above if air were a constant density. For instance, if the mean barometric pressure is 29 in., the factor for 30° F. is 9,

for 40° F., 9·2; for 50° F., 9·4; if 30 in., the factor is 8·7, 8·9, 9·1 for the same temperatures.

The height is found by reading the barometric pressure, say, 30 in. at the foot of a hill with temperature 45° F., and 28 in. at the top with temperature 35° F., representing a difference of 200 hundredths of an inch. This gives a mean of 29 in. pressure and 40° F. temperature. Therefore the factor is 9·2 and the height is 9·2 × 200 = 1840 ft. Approximately 900 ft. of ascent will correspond to a drop of one inch of mercury, so to reduce to sea-level, one inch for every 900 ft. of height is added to actual barometric readings.

8. CAUSE AND TYPES OF RAIN

Cause of Rain.—Air at any given temperature and pressure can contain a definite amount of water vapour uncondensed and invisible. When it contains the maximum amount it is said to be **saturated,** and the temperature at which saturation is reached is called **dew point.** If air is cooled beyond dew point some of the water vapour is condensed as mist or cloud, and if the cooling is continued, rain falls. Hence cooling of air is the primary cause of rain. Expansion on rising is the most usual cause of cooling. There are various causes of rising and they differentiate certain types of rain, namely:—

Relief Rain.—This is caused when air blowing from a relatively warm sea comes in contact with coastal mountains, is forced upwards and so cooled beyond dew point. The prevailing westerly winds bring heavy relief rain to the coastal districts of the British Isles, and of countries like Norway, where there is high land along the coasts.

Cyclonic Rain.—This is due to upward movement of air in connection with low-pressure systems or cyclones. (See Chapter IX., Polar Front Theory.)

Convectional Rain.—Land is heated by the sun, and when insolation (see page 122) is great, the air becomes very warm and rises in the form of convection currents. It thus expands and cools, thus producing rain. Equatorial rain over the land is largely convectional, the summer rain of the steppes and prairies is also largely of this type.

Rainfall Maps.—Usually in atlases and textbooks there is a map known as the mean annual rainfall map. It is based on averages for the whole year extending

through a series of years. Such a map gives a very fair idea of the average quantity of rain in various districts, and if of the world, the isohyet of 10 in. corresponds very closely with the dry deserts.

However, the geographer studying crop distribution or tree growth must know not merely how much rain falls in different parts of his regions, but also when it falls. That is, he must know whether it is largely seasonal, as in monsoon or Mediterranean lands, or whether it is evenly distributed throughout the year. Hence, something more than the mean annual map is necessary. A map for each month is helpful, as well as one for each season, and certainly one for both hot and cold seasons. Some maps show the total quantity of rainfall for each season, others the season's amount as a percentage of the year's fall.

Rainfall to a very great degree depends on wind-direction and relief. Wind direction is associated with the world systems of high and low pressure, so that in some degree isobar maps assist us in differentiating regions of heavy or light rain, and of seasonal variations in rainfall. As a rule, low pressure areas are associated with heavy rainfall, whereas high pressure areas, where the descending winds are dry, have much less rain.

In most good atlases there are climate maps adequate to illustrate points referred to in this chapter.

Exercises on Weather and Climate Maps are given on pages 228-35.

CHAPTER XI

MAP PROJECTIONS. LONGITUDE, LATITUDE, AND SCALE

1. GENERAL IDEAS ON MAP PROJECTION

A **Map Projection** is some method of representing on a sheet of paper the lines of latitude and longitude of the globe. Such lines are known as **parallels** of latitude and **meridians** of longitude. The earth is not a perfect sphere. It is relatively flat around the poles, and has been termed an "oblate spheroid of revolution," that is a figure produced by revolution of an ellipse around its shorter axis. The polar diameter is shorter than the equatorial diameter, but on a globe of, say, 5 ft. diameter, the difference would amount to only a very small fraction of an inch. For practical purposes the geographer may regard the earth as a sphere. When he wishes to make a map on a flat sheet of paper, it is necessary to adopt some means of transferring to this paper the network of parallels and meridians in such a way that some approximation to the actual network of a globe is produced. Absolutely perfect representation is impossible, for mathematical reasons, which need not be discussed here.

Though a globe is the only means of representing the earth's surface accurately, any globe large enough to show clearly the features of small but important countries would be both expensive to make and very cumbersome to use. Hence there is recourse to maps, which, though not mathematically perfect representations of the globe, can be made sufficiently accurate for all practical purposes if their limitations be understood and if the purpose of the map is borne in mind. The usefulness of a map for certain purposes depends upon the character of the projection used for the network of parallels and meridians. There are various ways of projecting these lines from the sphere to a sheet of paper. Each method of projection has its own advantages and disadvantages for specific purposes.

One projection may have both parallels and meridians as straight lines (**Mercator,** page 144); another may have them both as curves (**Bonne,** page 146); another may have curved meridians and straight parallels (**Mollweide,** page 150, where, as in Bonne, one meridian is a straight line); another may have curved

parallels and straight meridians (**Simple Conic,** page 138). These and other projections will be described in subsequent pages, and their usefulness for particular purposes will be noted. They are mentioned here to show that parallels and meridians, which are curved on the globe, can be shown as curves or straight lines on certain projections.

The positions of points upon the globe are by convention defined by reference to parallels of latitude and meridians of longitude, and it is for this reason that such lines must be represented on any sheet of paper where we wish to draw a map. Such representations are termed projections, though several of them are not projections in the sense understood by a mathematician. Either of the words **graticule** or **network** has been suggested in lieu of projection, but the term **projection** still holds its own in textbooks and atlases.

Certain qualities are looked for in projections, but they cannot all be seen in the same projection, and those which show most fully the qualities best applicable to specific purposes are selected when maps are to be used for such purposes. *The qualities which constitute a good projection centre round the degree to which it can preserve the relative area, shape, and scale, compared with the globe.* Another quality sometimes desired is the preservation of **bearing,** in other words, of direction. Also, a projection for general use should not be difficult to draw, nor should it involve elaborate and difficult mathematical calculations, though such drawbacks can sometimes be minimised by use of mathematical tables.

2. LONGITUDE, LATITUDE, AND SCALE

Before we can understand the practical methods underlying the construction of projections, it is necessary to grasp the meaning of longitude and latitude, and of scale as applied to the globe.

In the actual construction of projections, various methods are employed, the chief being (1) the so-called **graphical method,** which makes use of geometrical first principles (see page 141); (2) what is known as the **trigonometrical method,** use being made of trigonometrical formulae to find the length of parallels, and the radii to construct them when they are circles (see page 138). Sometimes recourse to mathematical tables is necessary for some of the more difficult projections. As a rule, an elementary knowledge of the first principles of trigonometry will suffice for many of the commoner projections. Some students prefer graphical methods, which give reasonably approximate results.

Examples are given of the construction of typical projections, but students desiring fuller treatment of the mathematics of map projections and detailed methods of construction, are referred to standard books on the subject, such as those mentioned on page 243.

LATITUDE.—Latitude is the angular distance north or south of the Equator.

Let the Fig. 59 represent the plane of a section of the globe cut downwards (N. to S.) through its axis, NS. Let C be the centre of the earth, and WE the plane of the Equator, and to aid graphic visualisation, imagine the earth to be a perfect sphere. The latitude of any place P on the surface of the globe is the angle made at C, the centre of the plane of the Equator, by this plane WE, and the line joining P to the centre of the earth.

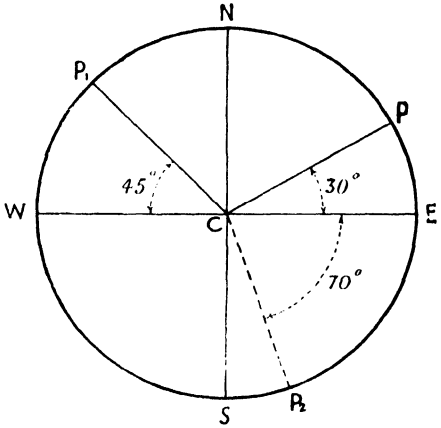


Fig. 59. TO ILLUSTRATE THE MEANING OF LATITUDE.

Thus the arc PE represents the latitude of P (30° N.), P_1W represents the latitude of P_1 (45° N.), P_2E represents the latitude of P_2 (70° S.).

To understand the figure, cut an orange downwards into two halves. The inside plane (fruity side) is represented by the circle WNES, which is a plane and will lie flat on the table.

To find the length of any parallel of latitude of the globe. Consider Fig. 60. $WxEy$ and $W_1x_1E_1y_1$ represent the Equator and another parallel of latitude, and each is the boundary (a circle) enclosing a plane surface. WC and W_1C_1 are radii of these circles respectively.

The latitude of the parallel $W_1x_1E_1y_1$ is the angle W_1CW (termed for convenience ϕ).

Now WC = W_1C (radii of same circle) and is represented by R, the radius of the globe.

But the angle E_1W_1C = the angle W_1CW (because W_1E_1 is parallel to WE) and thus the angle $E_1W_1C = \phi$.

Therefore $W_1C_1 = R \cos \phi$; but since W_1C_1 is the radius of the parallel $W_1x_1E_1y_1$ the length of the parallel $W_1x_1E_1y_1$ is $2\pi R \cos \phi$.

Note.—The length of a degree of latitude is everywhere about 69 ml., though there are slight variations due to the fact that the earth is not a perfect sphere. Thus the degree of latitude is 68·7 ml. at the equator, 69·4 near the poles.

LONGITUDE.—A meridian of longitude is a line passing entirely round the globe and through the poles, and is always what is known as a *great circle*. A great circle passes entirely round the globe, and its plane passes through the centre of the globe.

Longitude is measurement east or west of a first or standard meridian, and is

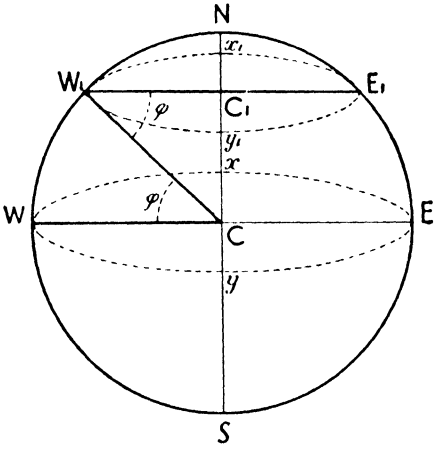


Fig. 60. LATITUDE.
To find the length of any parallel of latitude of the globe.

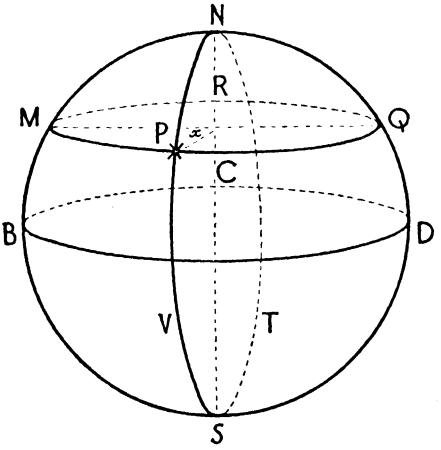


Fig. 61. THE MEANING OF LONGITUDE.

measured in degrees and their fractional parts (minutes or seconds). A circle, or complete turn, represents 360 degrees, therefore there will be 180° west and 180° east of the standard meridian. The longitude of a place is measured along the parallel of latitude on which the place is situated.

In Fig. 61, BCD is a great circle, the Equator; MRQ is a *small circle*, a parallel of latitude other than the equator; NVST is a great circle formed of the two meridians of longitude NVS, NTS; NS is the earth's axis.

If NMB is the first meridian (that of Greenwich), the longitude of any place P is measured by MP. This in degrees is equal to the angle x subtended by MP

at the centre of the circle MPQR. This angle is equal to the angle between the planes NMB, NPS, that is the angle between the tangents at N to the arcs NM, NP. Hence, *the longitude of a place is equal to the angle at the pole between the first meridian and the meridian of the place.*

At the Equator the length of a degree of longitude is $\frac{1}{360}$ of the equatorial circumference of the globe, or, in other words, $\frac{1}{360}$ of the Equator, and is approximately 69 ml. At the poles, where all meridians meet, the length of a degree of longitude will be zero. Anywhere else, that is, off the Equator and poles, the length of a degree of longitude is expressed by the trigonometrical formula Cos ϕ times the length of a degree at the equator, ϕ representing the latitude of the place, the formula thus being 69 . cos ϕ ml. approx.

The approximate length of a degree of longitude in miles for every 10° of latitude is as follows:—

0° (equator)	69·2 ml.	50° lat	44·6 ml.
10° lat.	68·1 „	60°	34·7 „
20°	65·0 „	70°	23·7 „
30°	60·0 „	80°	12·5 „
40°	53·1 „	90°	0 „

Scale.—In the construction of projections, as with all maps, it is necessary to consider scale. In Chapter II. the subject of map scales is treated in some detail, but for projections we must consider a few special applications.

Assume the earth to be a sphere with radius 3,960 ml., or approximately 250,000,000 in. Globes with a radius of 1 in. and 10 in. respectively would be on a scale of 1 : 250 million and 1 : 25 million respectively. Scale has the significance of a ratio, and to say that a globe is on a scale of 1 : 250 million is to imply that in the model globe every length is theoretically one-two-hundred-and-fifty millionth part of the original. On such a small scale it is impossible to show anything but the most general measurements of the globe.

On a scale of 1 : 125,000,000, R, the radius of the globe, = 2 in.
„ 1 : 100,000,000 „ „ = 2·5 in.
„ 1 : 10,000,000 „ „ = 25 in.

If this is understood, there will be no difficulty in working out scales for any projection, given the radius (R) of the sphere.

CHAPTER XII

MAP PROJECTIONS: GENERAL CLASSIFICATION; ZENITHALS, CONICALS

1. INTRODUCTORY

Projections are usually classed broadly as (1) zenithal, (2) conical, (3) cylindrical, these terms being derived from methods of construction. Broadly, zenithals are useful for the polar regions,[1] cylindricals are more suitable for equatorial regions than for higher latitudes, for which conicals are better. In addition, there are rather loose generalised classifications known as (4) modified conical projections, and (5) conventional projections. The uses of some of the better-known will be discussed later.

From the geographer's point of view, the term projection is not necessarily used in the strict mathematical sense. It is used rather to indicate some method of showing on a plane surface, that is, on a sheet of paper, the parallels and meridians as nearly as possible as they would appear on a globe.

2. ZENITHAL PROJECTIONS

Sometimes we are told to imagine a globe, say, of glass, on which the parallels and meridians are represented by black lines, and to imagine at the centre of the globe a small electric light bulb, whose rays could be focused on some particular point of the globe. We are to suppose it is possible by means of the light to photograph on a sheet of sensitised paper the parallels and meridians. The lines on such a photograph, we are told, would constitute what is known as a projection.[2]

[1] Some authorities emphasise the usefulness of the Oblique and Equatorial Zenithals (page 133) for continents and large countries. In Dierke's *Schulatlas*, for instance, they are thus largely used. For particulars of their construction, reference should be made to *Study of Map Projections* by J. A. Steers.

[2] This is only given as an illustration and is not a practical method. Any attempt to project the meridians and parallels as shadows on to a cylinder or cone would not give cylindrical or conical projections of any value. Nor could it actually be used for the zenithal projections.

Projections according to this plan made on a sheet of paper supposed to touch the globe at some selected point are called **zenithal** or **azimuthal** projections. The paper touches the globe at the centre of the map. Azimuth means a true bearing, and bearings from the centre of such a projection, *i.e.* from where the plane touches the globe, are true.

Zenithals may be classed according to the position of the point where the paper touches the globe. If the paper touches the globe (1) at either of the poles, it is termed a polar zenithal; if (2) at the equator, an equatorial zenithal; if (3) at some point between pole and equator, it is known as oblique zenithal.

Zenithal projections are also classed according to the position of the light which is supposed to reflect the shadow of the graticule on to the projection. If the light is at the centre of the globe the projection is termed *gnomonic* or central (see Fig. 62): if at the end of a diameter, it is known as the *stereographic* (see Fig. 63): if, however, the light is at infinity, the projection is termed *orthographic* (see Fig. 64). In the last-named case the rays are reckoned as parallel to one another, and are at right angles to the plane surface, *i.e.* the sheet of paper, touching the sphere.

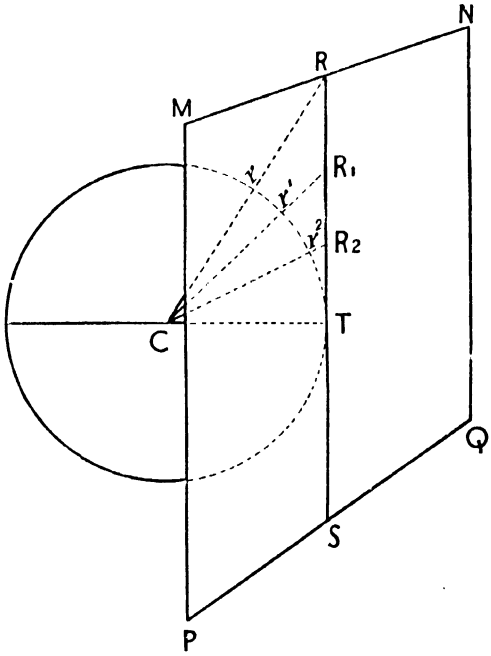


Fig. 62. Gnomonic Projection.

In Figs 62, 63, and 64, MNPQ is the sheet of paper on which the graticule is projected. The sheet touches the sphere at T, and RTS is a **tangent.** Here the sheet touches the sphere at the Equator, giving the equatorial case. If it touches the sphere at the pole, we have the polar case. In Fig. 64 the eye of the observer is supposed to be an infinite distance from the earth and cannot be shown on the diagram. Lines drawn from it, such as C_1R_1, C_2R_2, C_3R_3, are parallel.

In the gnomonic, the scale along the parallels (circles) is too great except near

the centre, and similar exaggeration of scale occurs on the meridians (straight lines), increasing with distance from the centre. This projection is not very useful for atlas or other maps; distance, area, and shape being very incorrectly represented. On it, however, what is a great circle on the globe is shown as a straight line.

In the stereographic, the scale along the parallels (circles) and the meridians is too great, but in each case increases from the centre less than in the gnomonic. Area in the stereographic is not true, but distortion is less than in the gnomonic. The projection is useful for hemispheres on a small scale, and is not difficult to draw. In older atlases it is seen for hemispheres and continents, but it is not much used to-day. The orthographic is of little use for atlas maps, but it is used by astronomers.

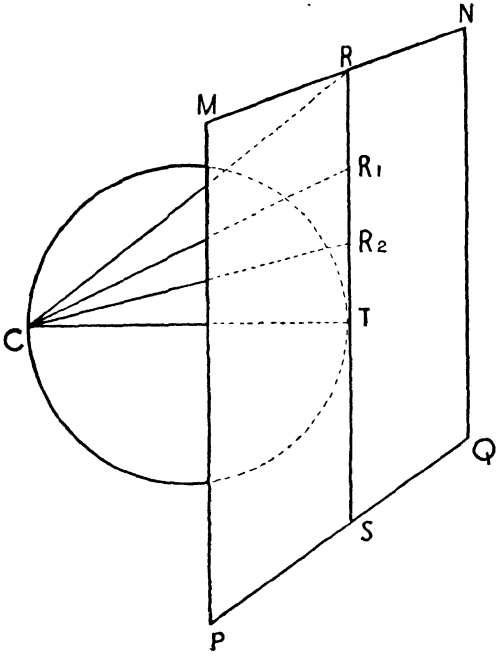


Fig. 63. Stereographic Projection.

Construction of the Gnomonic Zenithal (polar case). Take a line as first meridian (represented by 0° in Fig. 65), and mark off on it distances to represent (according to scale) the distances between the parallels required on the graticule. Then, with a common centre (N) on the meridian, or on it produced, draw concentric circles passing through the marked points. Such circles are the parallels. The meridians can easily be spaced with a protractor, angles (*e.g.* *a*N*b*) at the centre of the graticule being laid off to correspond with the angular measurement between two meridians. (In Fig. 65 these angles, *e.g.* 0, are 30°.)

Spacing for the parallel (latitude) intervals, e.g. *bc, cd,* is obtained from a table giving the cotangents of the latitudes for which parallels are to be drawn (see p. 135).

This projection is of little use except for the polar regions, because distortion increases with distance from the pole.

Some trigonometrical ratios for use with formulae for map projections are now given.

	sin	cos	tan	cot	cosec	sec
80°	0·9848	0·1736	5·6713	0·1763	1·0154	5·7588
70°	0·9397	0·3420	2·7475	0·3640	1·0642	2·9238
60°	0·8660	0·5000	1·7321	0·5774	1·1547	2·0000
50°	0·7660	0·6428	1·1918	0·8391	1·3054	1·5557
40°	0·6428	0·7660	0·8391	1·1918	1·5557	1·3054
30°	0·5000	0·8660	0·5774	1·7321	2·0000	1·1547
20°	0·3420	0·9397	0·3640	2·7475	2·9238	1·0642
10°	0·1736	0·9848	0·1763	5·6713	5·7588	1·0154

3. CONICAL PROJECTIONS

If a sheet of paper is rolled to form a cone which can be fitted on to a globe, this cone will serve as the basis of a projection. The cone is best adjusted so that its apex lies on the produced axis of the globe. If this is done, the cone touches the globe along a line of latitude known as the **standard parallel.**

The principle of *Conical projection with one standard parallel* is shown in Fig. 66. Here the plane of projection is the surface of a cone BCD fitted on the globe and touching the surface along the parallel TT_1T_2, which is the parallel of 50° N. The radius CT of the standard parallel is given by the formula R cot ϕ (see table above), where ϕ is the latitude of the standard parallel, here 50°, and R is the radius of the globe.

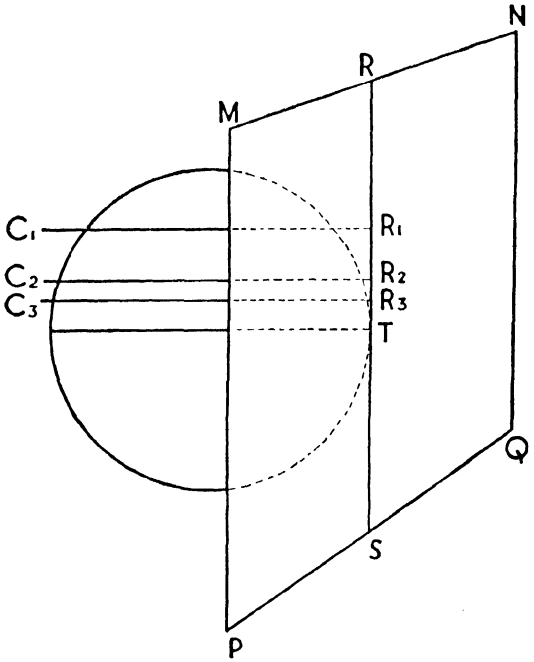


Fig. 64. Orthographic Projection.

$TT_1T_2T_3$ represents a plane section of the globe bounded by the parallel of 50° N. The diameter of this plane surface is TT_2.

Similarly $EE_1E_2E_3$ represents the plane surface of the section bounded by the Equator, and the equatorial diameter is EE_2. CM, CM_1, CM_2, etc., are meridians on the cone. Dotted curves represent portions of the globe covered by the cone.

If BMM_1M_2D is taken to represent $EE_1E_2E_3$, then CB = North Pole to E, and CD = North Pole to E_2.

If the cone is spread out it will represent the map shown in Fig. 71, from which construction of meridians is easy to follow.

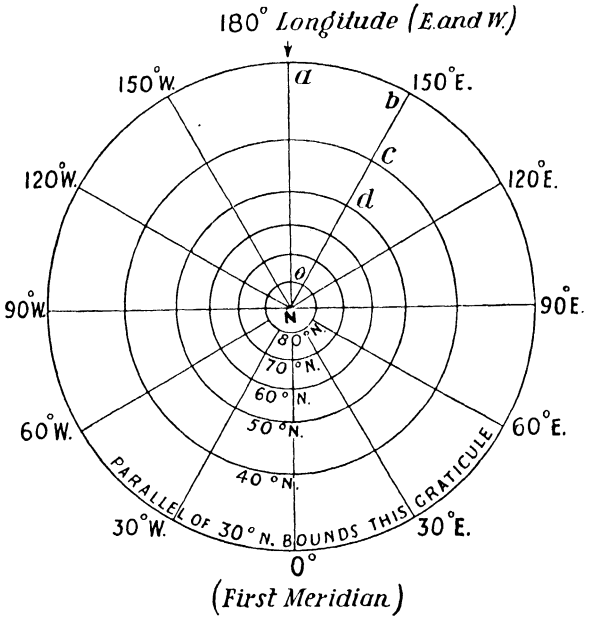


Fig. 65. A Zenithal Projection (the Gnomonic). Polar case for North Polar regions.

The cone cannot be tangent to the sphere along both of two parallels. However, two standard parallels can be made correct to scale in a conic projection. The cone, however, in this case must be regarded as quite independent of the globe and in no way touching or cutting it. If the cone cuts the sphere along two parallels, the projection is true secant conic. A secant is a straight line cutting the circumference of a circle at two points, and in Fig. 67 is shown by line PR or PS, part of which is dotted between parallels 50° N., 30° N.

Fig. 67 illustrates the *secant conic*, which is not a good practical projection. The cone PRMS is supposed to be sunk into the sphere in such a way that it cuts the surface of the sphere along two parallels, here those of 50° N. and 30° N. PM, PM_1, PM_2, etc., are meridians. $EE_1E_2E_3$ represents the plane surface of the section bounded by the equator, and the equatorial diameter is EE^2. This projection must not be confused with the *Simple Conical projection with two standard parallels*, which is developed in quite a different way (see page 142).

One parallel in the Simple Conical projection with one standard parallel is true to scale, and in the Conical projection with two standard parallels, two standard parallels are true to scale. Though the standard parallels are true to scale, other parallels in the projection are not. They are proportionally greater than the corresponding parallels in the actual sphere, the deviation from true scale being greater for increase of distance from the standard parallel. That is, if the standard parallel is 50° N., there will be greater error along the parallel of 80° N. than

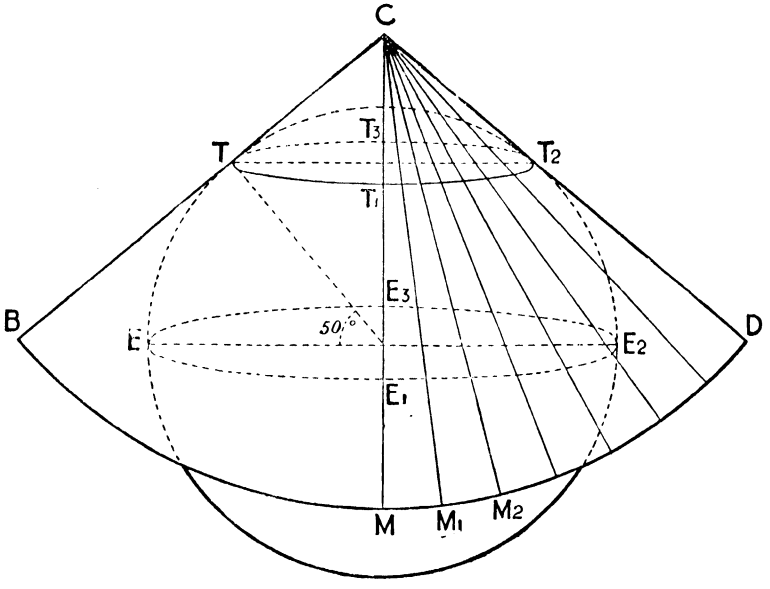


Fig. 66. Principle of Conical Projection with One Standard Parallel.
See page 138 for construction of graticule.

along that of 60° N., and greater along 5° N. than 45° N. By saying that the standard parallels are true to scale, we mean that if a map is drawn on a scale of 1 : 5 million, the length of the parallel on the projection will be one five-millionth part of the corresponding parallel on the actual globe. The other parallels which are not true to scale do not show such proportion. On parallels external to two standard parallels, scale is too great; on parallels between them it is too small. (See Figs. 68, 69.)

In conical projections with one standard parallel or with two standard parallels, the meridians are all true to scale and are correctly spaced. The angles which the meridians make with each other at the apex of the cone are a certain fraction of the angles made at the poles by the meridians on the actual sphere. This fraction, which is known as the constant of the cone, is usually conventionally represented by a symbol, say, n. This is useful in reckoning the meridian limits of a conic graticule.

In conical projections the meridians are represented by straight lines which

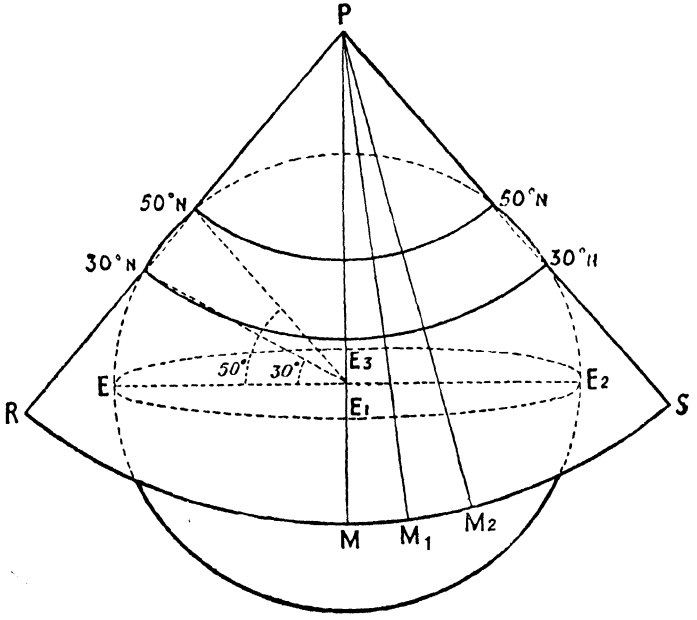


Fig. 67. True Secant Conic Projection.

converge to a point. This point is the vertex of the cone, and concentric circles described about it represent the parallels. The pole is represented by an arc, which shows that such projections do not truly represent the surface of the globe.

The conic is treated more fully than other projections in order to illustrate various methods and properties connected with projections.

To construct the Simple Conical projection with one standard parallel (trigonometrical method). It is first necessary to know the relation of the radius of the globe to the radius of the standard parallel and its length.

Consider Fig. 70. TP is the radius of the standard parallel on the projection.

If R is the radius of the sphere and ϕ represents the latitude[1] of the standard parallel, then TP = R cot ϕ, because angle TPC = angle TCE.

The radius of the parallel of latitude ϕ on the globe is QT, which is equal to R cos ϕ, because angle QTC = TCE. Thus the length on the projection of the parallel whose radius is QT is 2π R cos ϕ.

We will now proceed to construct a Simple Conical projection with one standard parallel, 40°.

Use scale of 1 : 50 million ($R = 5$ in.).

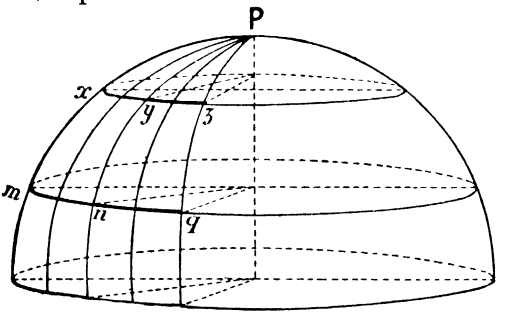


Fig. 68. Part of Sphere.

Representation on globe of part of parallels *xyz*, *mnq*, and part of meridian *xm*, *yn*, *zq*. Compare with Fig. 69, which shows corresponding conical projection.

With radius R cot ϕ = 5·96 in., and centre C, describe a circle (*e.g.* MPQ), on which mark off arc MQ = $2\pi R$ cos ϕ, *i.e.* 24·06 in., to represent the standard

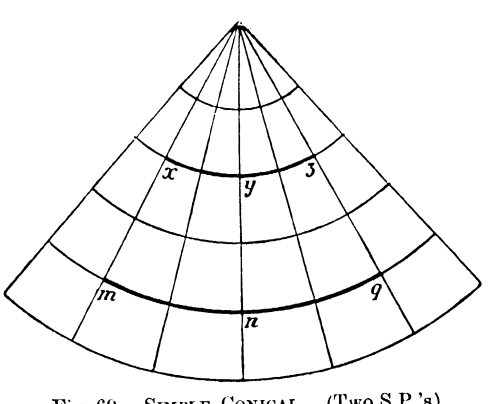


Fig. 69. Simple Conical. (Two S.P.'s)

Projection of the parallels and meridians shown on part of sphere in Fig. 68. (Page 142 gives method.)

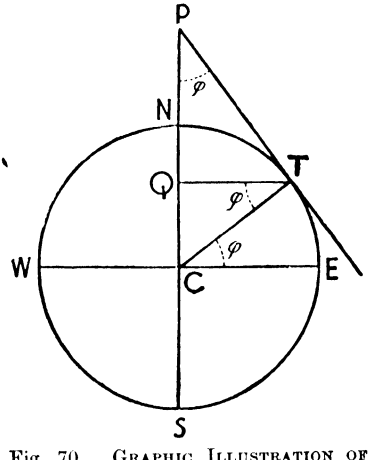


Fig. 70. Graphic Illustration of Formula for Simple Conic. (One S.P.)

parallel (Fig. 71). If the meridians are to be 10° apart, divide the arc into 36 parts

[1] Latitude is an angular measurement, see p. 129.

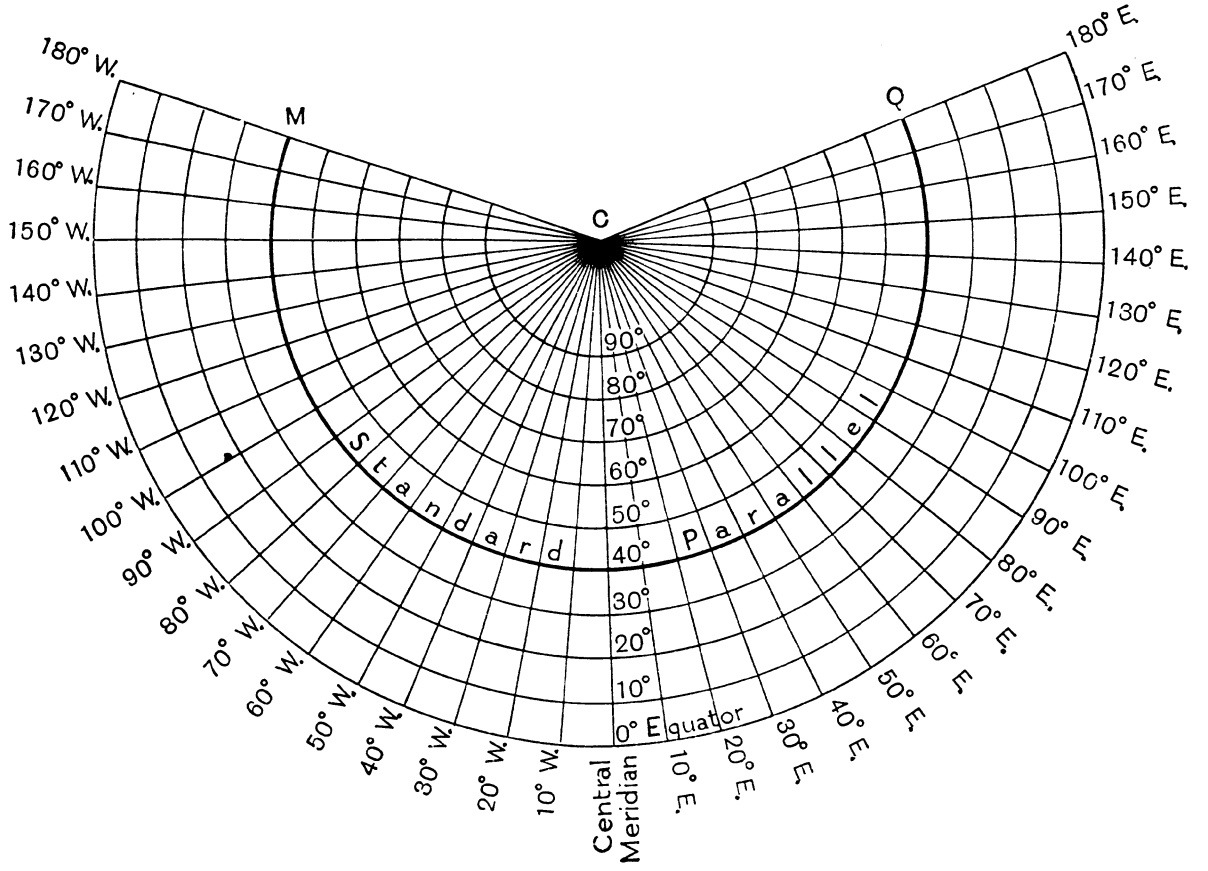


Fig. 71. Simple Conical Projection with One Standard Parallel.
In practice only a limited part of this graticule would be drawn.

(a circle representing turning through 360°), and then join each point of division to the centre of the circle, the point which represents the apex of the cone.

To obtain, 10° apart, parallels other than the standard parallel, mark off on the central meridian divisions represented by $2\pi R$ divided by 36, *i.e.* 0·87 in., and, with same centre as for standard parallel, describe arcs to pass through these points of division.

For the properties of this projection see page 137. It is suited to relatively small countries with little extent of latitude, *e.g.* Denmark, Ireland, Poland. For areas with wider extent of latitude, *e.g.* Russia, Scandinavia, the conic with two standard parallels is preferable. This is also sometimes used for Europe.

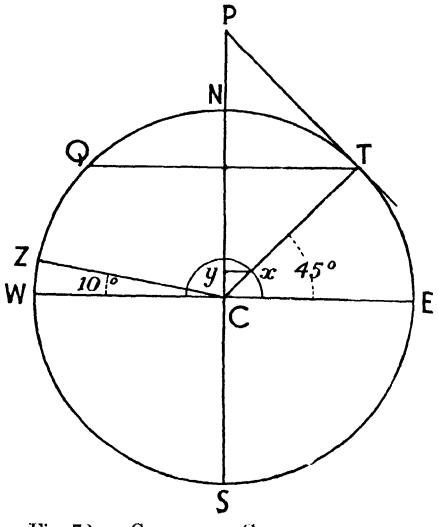


Fig. 72*a*. Graphical Construction of Simple Conic. (One S.P.)

To construct the Simple Conical projection with one standard parallel (graphical method). Describe the circle WSE to represent the globe on the required scale. (See Fig. 72*a*.)

Make the angle TCE to represent the latitude of the standard parallel.

Draw WCE to represent the Equator and NS to represent the polar axis, which produce.

Where TQ, the radius of the standard parallel cuts the circle at T, draw the tangent TP.

On the projection take any line, PC, as the central meridian. (See Fig. 72*b*.)

With radius PT, as in Fig. 72*a*, draw the standard parallel MN.

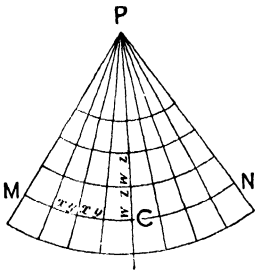


Fig. 72*b*. Simple Conic. Compare with method of Fig. 71.

For every degree of latitude (1°) the parallels are $\frac{2\pi R}{360}$ units of length apart. If spacing of 10° is required, mark off on the central meridian $\frac{2\pi R}{36}$ units of length above and below where the meridian and parallel intersect.

To divide the standard parallel at intervals of 10°, make the angle ZCW equal to 10° (Fig. 72*a*). With radius WZ and centre C describe an arc (really a semicircle). From where the arc cuts TC draw *xy* perpendicular to NC (polar axis) and parallel to WE (Equator).

On the projection (Fig. 72*b*) mark off on the standard parallel divisions equal to *xy*. Draw the remaining meridians by joining these points to P.

On the central meridian mark off distances equal to WZ. From each of these points to P is the radius of the other parallels.

To construct a simple Conical projection with two standard parallels. Two concentric circles must be drawn to represent these parallels, and their length must be correct. The distance between them must be equal to the true curved distance between the selected parallels on the sphere.

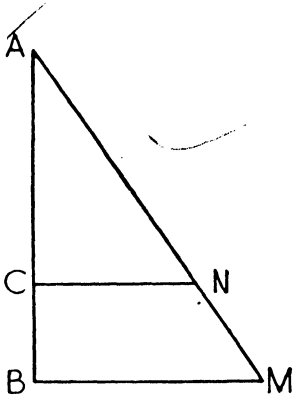


Fig. 73.

Draw (Fig. 73) any straight line AB, and mark off on it BC equal to the true curved distance (such as *ny* or *qz* on Fig. 68) between the selected parallels on the sphere. From B and C draw BM, CN, perpendicular to AB and equal to given lengths (say *mq*, *xz* in Fig. 68) of the selected parallels on the sphere. Join MN and produce to meet AB at A. Then AC, AB, are radii of the standard parallels on the projection.

Fig. 69 shows the graticule. The standard parallels *mnq*, *xyz* are drawn from a common centre with the radii found above. Take a central meridian through *y* and *n*. Space that part of it between the standard parallels so as to give the required latitude intervals, which also mark off above and below the standard parallels. Such divisions give the radii of the other parallels, which are drawn from the common centre. The parallels are divided correctly by the formula $\frac{2\pi R \cos \text{lat.}}{360}$ for every degree, and the meridians are inserted like those of the Simple Conic with one standard parallel.

CHAPTER XIII

MAP PROJECTIONS: CYLINDRICALS, CONVENTIONAL PROJECTIONS; CHOICE OF PROJECTIONS

1. CYLINDRICAL PROJECTIONS

A sheet of paper rolled in the form of a cylinder and placed around the globe gives what is termed a cylindrical projection. The cylinder may touch the globe along any great circle, lines of latitude and longitude on the globe being projected on the cylinder.

If the area between two parallels of latitude on the projection is made to correspond with what it would be on the globe, the **cylindrical equal area** results.

The graphical construction of this projection is simple. (See Fig. 74.)

Given the scale of the globe, say 1 : 125 million, the radius R of the globe will be 2 in. With this radius draw a circle and then WE will represent the Equator. Suppose the parallels of latitude are to be 30° apart, make angles of 30° subtending arcs Em, mp, pN, Em', $m'p'$, $p'S$ on the circumference.

Then through the points m, p, N, m', p', S draw, parallel to the Equator, lines which are the parallels of latitude.

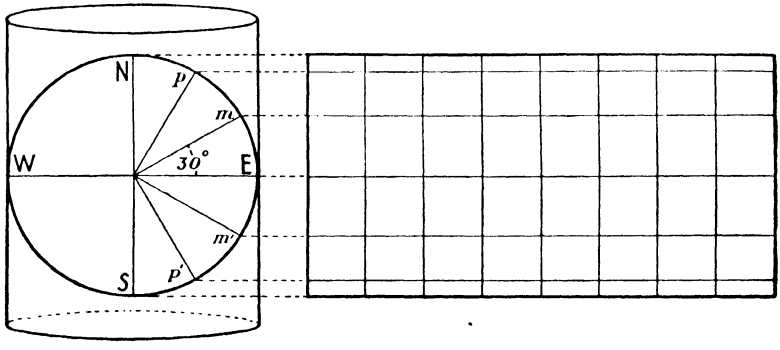


Fig. 74. CYLINDRICAL EQUAL AREA PROJECTION.

The intervals between the parallels of latitude decrease from the Equator to the poles. They vary as the sines of the angles of latitude.

The Equator is drawn according to scale, and the meridians are spaced at equal distances along it.

MERCATOR'S PROJECTION.—A much used and well-known cylindrical projection is that of Mercator, which dates as far back as 1569. The meridians are equidistant vertical straight lines correctly spaced in 0°. Parallels are horizontal

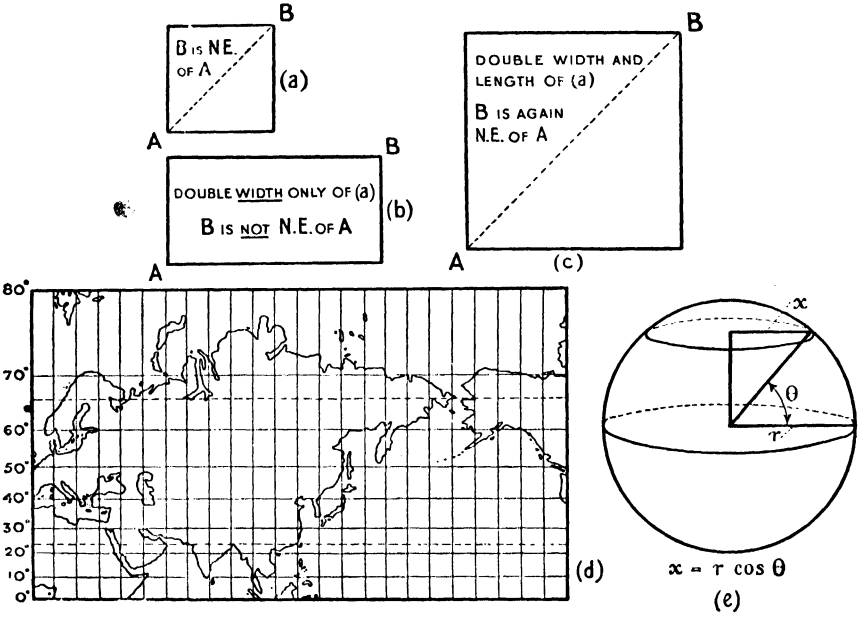


Fig. 75. MERCATOR'S PROJECTION.

straight lines. They are not equidistant, but to preserve the correct ratio between degrees of latitude and longitude, their distances apart are increased as the latitude increases. The exact construction of Mercator's projection involves much mathematics or recourse to tables prepared for the purpose, but the following will convey some idea, in an elementary way, of the general principle.

Assuming the earth to be a perfect sphere, the radius of the (small) circle round the globe representing, say, latitude 45°, is equal to the radius of the (great) circle representing the equator, multiplied by cos 45° [*i.e.* multiplied by $\frac{1}{\sqrt{2}}$–Fig. 75 (*e*)]. The length of a degree of longitude at the equator is therefore $\sqrt{2}$, or 1·414 times that of a degree of longitude at latitude 45°. In Mercator the length of a degree of longitude at latitude 45° is made equal to that of a degree at the equator, for the longitudinal lines are parallel lines. Thus the length of a degree of longitude at latitude 45° is increased $\sqrt{2}$ times, and therefore the length of a degree of latitude here must also be increased $\sqrt{2}$, or 1·414 times, to preserve the correct ratio [Fig. 75 (*a*), (*b*), (*c*)]. At latitude 60° the length of a degree of longitude is really only about half the length of a degree at the equator (cos 60° = $\frac{1}{2}$): on Mercator the length is the same, so that the scale of longitude along the parallel of 60° is double the scale on the Equator, and to preserve true proportions, the scale measured north and south must also be doubled (Fig. 75). Thus on Mercator the distance from latitude 60° to 61° is approximately twice as great as from latitude 0° to 1°, though on the globe these distances are equal. Similarly, it can be shown that at longitude 80° the length of a degree is increased 5·76 times (approx.), and so on. On this projection the shape of the land masses is approximately preserved, but area in high latitudes is much exaggerated. Alaska is shown nearly as large as the United States, though its area is only about one-fifth that of the States.

2. MODIFIED CONICAL AND CONVENTIONAL PROJECTIONS

In addition to the zenithal, conical, and cylindrical projections, there are a number of miscellaneous projections which are usually classed under the headings of modified conical and conventional projections. Such headings, especially that of conventional projections, are rather vague, but they suggest that there are projections which do not readily fall into the three broad divisions of azimuthal, conical, and cylindrical. They include some of the most useful and most commonly used.

Of modified conical projections, Bonne's and the Sanson-Flamsteed (sometimes termed the sinusoidal) are well known. A familiar conventional projection is the Mollweide.

3. BONNE'S MODIFIED CONICAL PROJECTION

In Bonne's projection the **standard parallel** is drawn from the data $R \cot \phi$, that is, radius of the globe multiplied by cotangent of the latitude. The **central meridian** is a straight line divided as with the simple conic, *i.e.* $\frac{2\pi R}{36}$ to give intervals of 10°. The parallels other than the standard parallel are concentric circles drawn through these points of division, their centre being the same as for the standard parallel. *Meridians other than the central meridian* are obtained by (1) dividing each parallel according to the interval required between each meridian, and then (2) by connecting corresponding points on the parallels. By "corresponding" points we mean those relating to the same meridians. Thus meridians other than the central one will be curves.

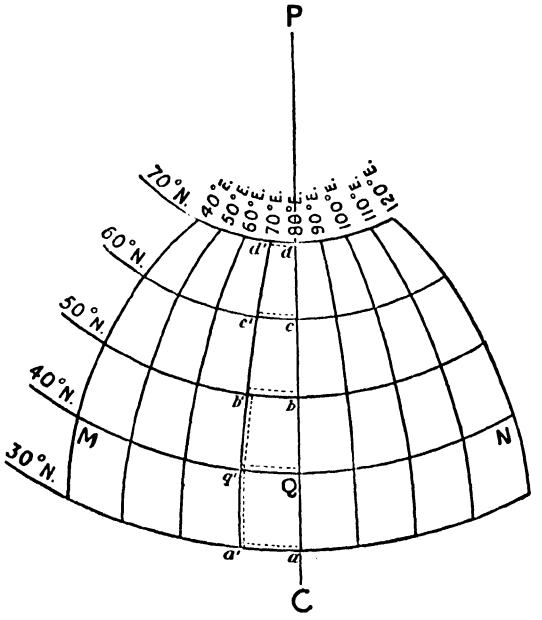


Fig. 76. BONNE'S PROJECTION. (Development.)

This projection is equal area. The meridians other than the central one, being curves, are too long and do not cut the parallels at right angles. Hence the projection is not orthomorphic. The parallels and the distances between them are true to scale on the central meridian, but, for a wide extent of latitude, there is considerable distortion at the extremities, as, for instance, in the N.W. and N.E. of Asia.

This projection is largely used for atlas maps, both for continents and countries which are sufficiently compact to avoid distortion at the corners.

Method of constructing Bonne's projection on scale of 1 : 50 *million* ($R = 5$ *in.*). We will take a net with 10° as meridian and parallel interval, 80° E. as central

meridian, and 40° N. as standard parallel, the longitude limits being 40° E. and 120° E., the latitude limits being 30° N. and 70° N.

Radius of parallel 40° N. $= R$ cot 40° $= 5{\cdot}96$ in. approx.

Latitude intervals (for 10°) on Central Meridian $= \frac{2\pi R}{36} = 0{\cdot}87$ in. approx.

Longitude intervals (for 10°) on standard parallel $= \frac{2\pi R \cos 40°}{36} = 0{\cdot}67$ in. approx.

Longitude intervals for other parallels $= \frac{2\pi R \cos \text{lat.}}{36}$ viz. for 30° N. $=$ 0·76 in.: for 50° N. $=$ 0·56 in.: for 60° N. $=$ 0·44 in.: for 70° N. $=$ 0·30 in.

Draw PC as central meridian. (See Fig. 76.)

With centre P and radius 5·96 in., describe the arc MQN to represent the standard parallel 40°.

From Q downwards and upwards mark intervals of 0·87 in., *i.e.* Q*a*, Q*b*, *bc*, *cd*.

With centre P and radius P*a*, P*b*, P*c*, P*d*, draw arcs to represent the parallels 30° N., 50° N., 60° N., 70° N., respectively.

Along these parallels, starting from the central meridian mark to the left and to the right intervals corresponding to the longitude intervals noted above, viz. 0·76 in. for *aa'*, 0·67 in. for Q*q'*, etc.

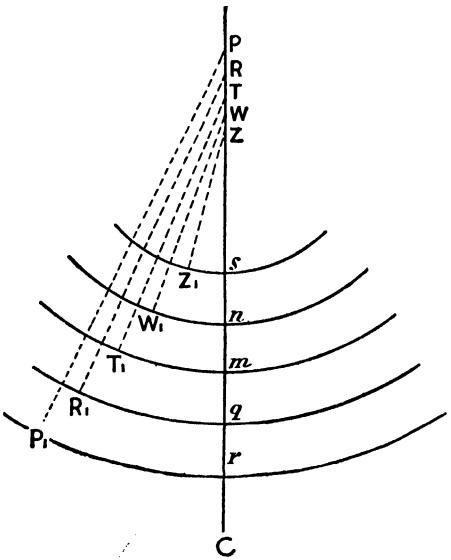


Fig. 77. Polyconic Projection.

Join the corresponding points on each parallel, viz. *a'*, *q'*, *b'*, *c'*, *d'*, and curves representing the meridians will result.

4. POLYCONIC PROJECTION

Each parallel is a circle, drawn with its own centre and radius. The radius for each parallel is R cot lat., as with the simple conic. The central meridian is divided as in the simple conic, length of 1° of latitude on the central meridian

being $\frac{2\pi R}{360}$. The parallels are divided as in Bonne, *i.e.* $\frac{2\pi R \cos \text{lat.}}{360}$ for 1° of longitude.

To Draw the Polyconic Projection. (Scale 1 : 50 million; $R = 5''$.)

Draw a straight line, PC, to represent the central meridian. (See Fig. 77.) Take any point, *m*, in it and for intervals of 10° latitude, mark off on this meridian $\frac{2\pi 5}{36}$ in intervals, *q*, *r*, *n*, *s*, etc. Take these points, *m*, *n*, etc., as guides for radii of the circles which will represent the parallels, *i.e.* *m*T is required radius for parallel $m\text{T}_1$, therefore T will be centre for describing this parallel.

Centres of the arcs representing parallels are on the line PC, the arcs being drawn through *m*, *n*, *q*, *r*, *s*, respectively.

Thus 60° with radius $R \cot 60° = 5 \times 0{\cdot}5774$ in.

50° ,, $R \cot 50° = 5 \times 0{\cdot}8391$ in.

Divide these parallels for 10° of longitude.

$$60° \quad \frac{2\pi R \cos 60}{36} = \frac{2\pi 5 \times 0{\cdot}5}{36} \text{ in.}$$

$$50° \quad \frac{2\pi R \cos 50}{36} = \frac{2\pi 5 \times 0{\cdot}6428}{36} \text{ in.}$$

The One-in-a-million International map is drawn on a modified form of the polyconic. Unlike the latter, in which meridians are curves, the International meridians are straight lines. (In the polyconic parallels are circles, but not concentric).

Each sheet of the International is plotted separately on its own central meridian, a straight line. The boundary north and south parallels are plotted with radii derived from tables, but they are not concentric. The boundary parallels are like those of the ordinary polyconic divided truly according to scale. Meridians are drawn by joining these points. (See page 155 for combination of International sheets.)

5. THE SANSON-FLAMSTEED PROJECTION

To construct a **Sanson-Flamsteed** or **sinusoidal projection** for world maps draw a horizontal straight line WE to represent, on the given scale, the Equator, which may be taken as the standard parallel. Bisect it at O and draw, perpendicular to WE, straight lines ON, OS, which represent meridian length from the North Pole to the Equator and the South Pole to the Equator respectively. The central meridian is NS, which is half the Equator. Divide NS into 18 equal parts, each to represent 10° of latitude. Through each point of division draw a horizontal straight line to represent the parallels 10°, 20°, 30°, 40°, 50°,

60°, 70°, 80° respectively. These straight lines should, according to scale, correspond with lengths of the parallels on the globe, and should be bisected by the central meridian. For practical purposes the lengths of parallels on the globe may be ascertained from tables. The length of any parallel on the globe is $2\pi R \cos$ lat., where R represents the radius of the globe.

Connect the ends of the parallels by curves, which will be the boundary lines of the world graticule, and will represent the meridians 180° W. and 180° E. To obtain, 10° apart, the meridians other than 0°, which is the central meridian, divide the Equator and all the other parallels into 36 equal parts, and by means of curves connect the corresponding points of division on the various parallels.

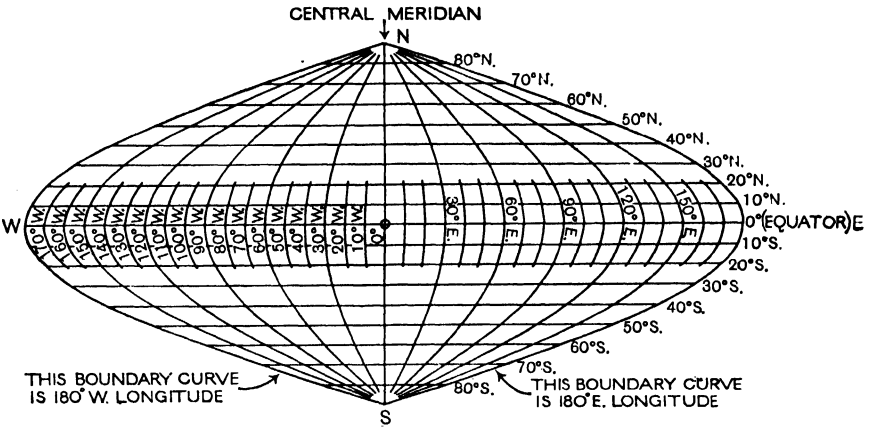


Fig. 78. Sanson-Flamsteed (Sinusoidal) Projection.

The Sanson-Flamsteed is an **equal area** projection. Parts of parallels forming the north and south sides of any quadrilateral on it are true to scale, and the perpendicular distance between them is correct. Trapeziums with corresponding parallel sides and heights are equal. Hence the area of any quadrilateral on the map is equal to the area of the corresponding quadrilateral on the globe. Those quadrilaterals on the Equator and central meridian correspond in shape to their fellows on the globe, but the further west or east we move on any parallel other than the Equator, the more distorted the quadrilaterals become, the distortion of shape being very marked as the boundary of the map is reached. Hence the projection is not a favourite one for world maps.

It is suitable for a continent or country which does not extend (1) too far north and south of the Equator; (2) too far east and west. Hence, by selecting the central meridian so that it passes through the centre of the continents, a useful graticule may be obtained for Africa or South America. If used for maps of Australia or North America there would be great distortion, as these continents are considerable distance from the Equator and have too much east-to-west extension. For similar reasons, the projection is not suitable for Asia, where there would be even greater distortion, and the east-to-west extension of Europe in relatively high latitudes rules out a sinusoidal graticule for that continent.

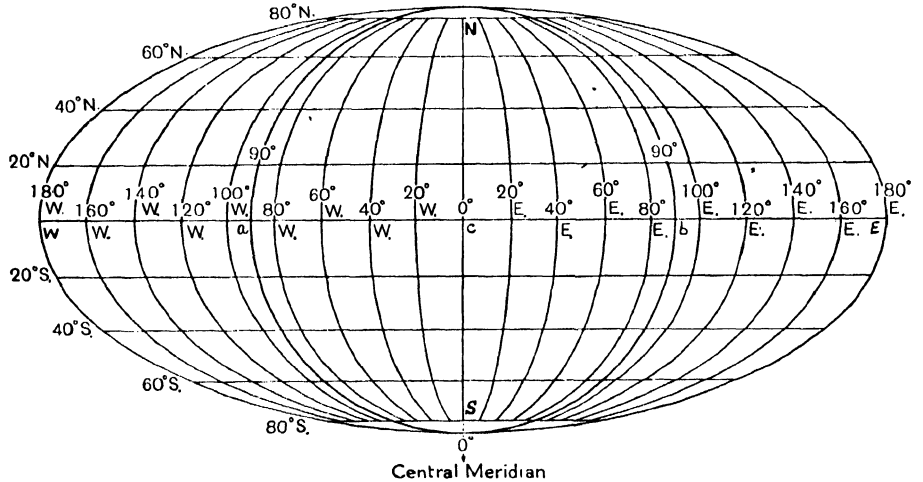


Fig. 79. Mollweide Equal Area Projection.

6. THE MOLLWEIDE PROJECTION

To construct a Mollweide projection, first draw a circle equal in area to a hemisphere (*i.e.* of a solid hemisphere) on the given scale. (See Fig. 79.) This is done by taking a radius $\sqrt{2}$ times, *i.e.* 1·414 times, that of the radius of a sphere. Produce the equatorial diameter *ab* east and west to E and W until it is twice the diameter of the circle *a*N*b*S, *i.e.* half the Equator on the projection, since we drew only a hemisphere. Through *c*, the middle point of *ab*, draw NS perpendicular to *ab*. NS is the central meridian. Complete the ellipse SWNE, which bounds the graticule on which the Equator is represented by WE.

Divide WE into 12 equal parts, each to represent 30° of longitude, and similarly divide each parallel. To represent meridians other than the central meridian draw elliptical curves from the points of division to the poles. The central meridian is the straight line which bisects the Equator at right angles.

The most difficult task in connection with this projection is to secure correct distances between the parallels. The parallels are drawn with the help of tables which give the distance between any parallel and the Equator. Such distances are not readily calculated directly. These distances are marked along the central

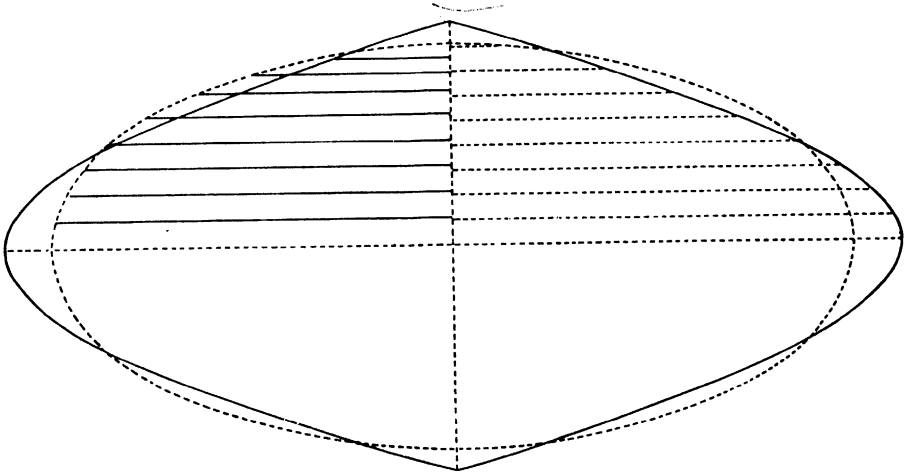


Fig. 80. Comparison of Mollweide and Sinusoidal Projections.

meridian, and through such points the parallels are drawn parallel to the Equator.

The following table shows for the Mollweide projection the relative distances of certain parallels from the Equator. These distances are in relation to the radius of the globe, namely, for

10°	parallel	of	latitude	...	0·194	times	the	radius	of	the globe
20°	,,	,,	,,	...	0·385	,,	,,	,,	,,	,,
30°	,,	,,	,,	...	0·571	,,	,,	,,	,,	,,
40°	,,	,,	,,	...	0·751	,,	,,	,,	,,	,,
50°	,,	,,	,,	...	0·921	,,	,,	,,	,,	,,
60°	,,	,,	,,	...	1·077	,,	,,	,,	,,	,,
70°	,,	,,	,,	...	1·219	,,	,,	,,	,,	,,
80°	,,	,,	,,	...	1·336	,,	,,	,,	,,	,,
90°	,,	,,	,,	...	1·414	,,	,,	,,	,,	,,

Mollweide is an equal area projection, and is generally represented by an ellipse with the Equator as a major axis. The frontispiece of the second edition of Hinks' *Map Projections* is a beautiful example of a transverse Mollweide with different major axis. On such a map most of the British Empire can be represented with little distortion.

In Professor C. B. Fawcett's *Political Geography of the British Empire*, the " skew " (oblique) Mollweide is successfully used for world maps.

The normal Mollweide, because of its equal area properties, is much used in atlases for distributional maps of the world. As a world map it is preferable to the Sinusoidal, because the distortion in higher latitudes is not so great. See Fig. 80, which gives a comparison of the two projections, Mollweide being shown by the dotted boundary, Sanson-Flamsteed by the continuous one. The Mollweide parallels are shown by straight, and Sanson-Flamsteed by dotted, lines, the equator (dotted) being common to both graticules.

7. CHOICE OF PROJECTIONS

When we select a projection for any map, there are several things to bear in mind. It is necessary to remember to what use the map is to be put, the position of the area to be mapped, and its extent with respect to latitude and longitude. Other things being equal, it is advisable to choose a projection reasonably easy to draw, and needing no abstruse mathematical calculation.

For distributional maps to show density of population or stock, distribution of cultivated crops or of natural vegetation, an equal area map is desirable, so that not only the actual distribution of the commodity can be noted, but also the relative size of the regions where it is found. Some projections show area fairly correctly to scale in certain latitudes, but distort it greatly in others.

For a world map, three well-known projections are the Cylindrical Equal Area, Mollweide, and Sanson-Flamsteed. No one of these is very difficult to draw. The first named is the easiest to draw, and for this reason would probably be selected for most purposes except for the fact that in high latitudes shape is much distorted, though the area is everywhere true to scale compared with the globe. There is little distortion between the tropics, so that it would be quite suitable for showing the distribution of products such as rice, rubber, or cane-sugar.

If the distribution of the temperate cereals, such as wheat or maize, is to be shown, the Cylindrical Equal Area would be less suitable, because the shape is much distorted where these crops are found. They are grown in large countries

like the United States and the Argentine, and the shape of these should be preserved, for ease in reading if for nothing else. Hence Mollweide or Sanson-Flamsteed would be preferable, and the former would probably be the ultimate choice.

For equal area of a single country or continent other projections are available Bonne's being a favourite with atlas makers. It is least suitable for Asia, because this continent has too great extension through both longitude and latitude to avoid distortion in the north-west and north-east corners.

Maps for small areas such as the British Isles, the Baltic Lands, France, or the Balkan Peninsula, whether required for distributional purposes or to show ordinary physical features or political geography, would probably be on the Simple Conic with two standard parallels. This projection is easy to draw, and, if the standard parallels are wisely chosen, is reasonably correct as regards scale, preserves shape better than Bonne, but is not equal area, a point not of great importance for small areas with not too great extent of latitude. It is suitable for any extent of longitude, which, with ease in drawing, would render it popular for maps of, say, the transcontinental railways like the Canadian Pacific and the Trans-Siberian.

For maps of the Polar Regions or of the Tundras, one of the zenithals is best, possibly the Zenithal Equidistant, which shows distances along the meridians and bearings (azimuths) from the Pole correctly.

The usefulness of the Oblique and Equatorial Zenithals for continents and large countries may again be stressed.

Where direction is desirable, for navigation on the sea or in the air, or to show the direction of ocean currents and planetary winds, Mercator is suitable. Distortion of area in high latitudes does not affect the main purpose for which the map would be used.

We have only mentioned some of the commonest projections. There are others less well known which for certain purposes may be very suitable, but which may be rather less easy to draw than those generally used by atlas makers. Several excellent but relatively little known projections are described in the books mentioned on page 243, especially that by Professor J. A. Steers.

Exercises on Map Projections are given on page 235.

Students should be able to recognise the various projections and to discuss their use for specific purposes. To do this some knowledge of the principles underlying their construction is necessary.

8. GRIDS

A grid is a combination of squares designed to facilitate reference to a map. It is not a graticule, latitude and longitude may be shown independently of the grid. Grids on Ordnance and other maps have comprised squares with letters in two parallel margins and figures in two others, so that the position of a feature or place might be referred to as A1, C4, etc. The method was simple in principle, but sometimes not very convenient in practice, especially when there were many names in a square. Its use was limited because the grid might refer only to a particular sheet of a particular edition of an Ordnance Survey map.

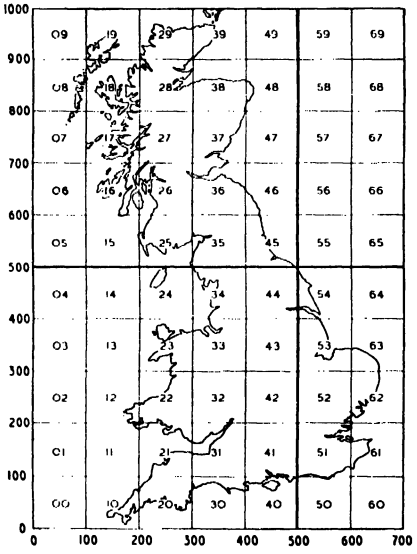


Fig. 81.

To-day all Ordnance maps are drawn on one projection, the Transverse Mercator, which makes possible the use of one National Grid and reference system. The grid is a series of lines drawn parallel to and at right angles to the central meridian to form a series of squares to cover the area represented on the map. The National Grid for Great Britain comprises seventy squares as shown in Fig. 81 on which the lines are numbered in kilometres. The lines forming squares are in the same relation to the detail on any map, whatever the scale, though the number of grid lines and their spacing is related to scale. On the one-inch and six-inch maps they are at intervals of one kilometre; on large-scale plans at intervals of 100 metres.

The point of origin of the projection used is 40° N., 2° W., but certain adjustments are made to minimise error in the central meridian, and instead of numbering the grid lines with the true origin of the projection as 0,0, a working origin has been used 400 kilometres further west and 100 kilometres further north, a point just south-west of Lands End. A point in the Mendip region (see map opposite page 32) may be referred to as being 365,743 metres east of the point of origin, and 157,381 metres north of the point of origin. As Eastings are written before Northings, the rather cumbersome reference may be written 365743 157381. On the quarter-inch

map reference to the nearest kilometre may suffice, but on the six-inch and one-inch maps reference to the nearest tenth of a kilometre may be advisable, so the corresponding references are 3657 1573, or in a shorter form 657 573. This is known as the Normal National Grid Reference, but in the Full National Grid Reference the number of the square is shown thus, 31/657 573.

In Fig. 81, reproduced by kind permission of the Controller, H.M. Stationery Office, the figures in the squares form part of the Grid reference and have no reference to the sheet numbers of maps.

9. COMBINATION OF SHEETS IN 1/M INTERNATIONAL MAP

Fig. 82*a* shows that a sheet of the International 1/M map will fit any one of its four surrounding sheets, but if further sheets are added, fit cannot be obtained

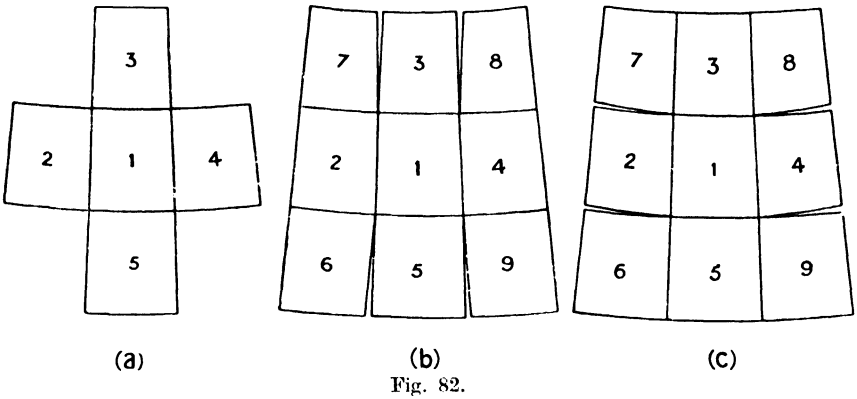


Fig. 82.

in all directions. Figs. 82*b*, 82*c* show two ways of distributing the misfit. Further combination is possible, *e.g.* in Fig. 82*b*, other sheets could be added to 2 and 4, and to 3 and 5 in Fig. 82*c*.

The International map differs from the ordinary polyconic in that the meridians are straight lines. Each sheet is plotted separately, with its own central meridian, the bounding parallels being arcs of circles whose centres are on the central meridian produced.

Each sheet covers an area of 4° of latitude and 6° of longitude, and though more than nine sheets do not fit well, it is possible to build up a map of large area without noticeable gaps.

PART II

CHAPTER XIV

SURVEYING AS THE BASIS OF LARGE-SCALE MAPS

1. THE FRAMEWORK OF TOPOGRAPHICAL MAPS

The object of the topographical surveyor is to record the relative position of various features on the earth's surface. From the geographer's standpoint, the results of a survey should be suitable for compilation of maps, and they must be as accurate as possible consistent with the scale. A traveller, for his own guidance, may make certain approximate observations as to the relative position of prominent objects along his route. Such observations, though approximate, are sufficient to enable him readily to retrace his steps to the abandoned site of a former camp or halting-place, but they may not be sufficiently accurate to serve as the basis for a map of previously unsurveyed country. Route traverses of the earlier travellers who, in the nineteenth century contributed much to our knowledge of interior parts of Africa and Australia, necessarily formed the groundwork of the first attempts to map such countries, but later and more carefully-made surveys showed them to be inaccurate in important details. This is not surprising, as the observations on which they were based were often made under difficult conditions, and not always with reliable instruments. As time goes on, scientific research requires more accurate maps. More precise instruments and methods enable more accurate maps to be made.

The type of surveying which gives the raw material of the large-scale official maps of various countries is known as **Topographical Surveying,** and such maps are usually termed *Topographical Maps.* Topography (from the Greek *topos,* a place, and *grapho,* I draw or depict) consists in depicting the various features of a district. The topographical surveyor, therefore, is concerned with methods which enable him to determine accurately and to summarise on a map the different features on the earth's surface. Such features may be either natural or artificial. Natural features include physical features such as mountains, hills, plateaux, and plains, where differentiation of relief is necessary; rivers, lakes, marshes, deserts, forests, natural grasslands. Artificial features are due to the agency of man

and may concern (1) *routes*, such as railways, roads, primitive tracks, references to crossing-places in the form of bridges and fords, works such as embankments, cuttings, tunnels, to overcome natural obstacles in a route; (2) *human settlement*, namely the sites of towns, villages, hamlets, or isolated dwellings.

A good topographical map will show the general relief and all the major surface features which can be included within the limitations of the map scale. On a small-scale atlas map of Lincolnshire, the county, even if the map attempts to show relief, appears to be an almost featureless level plain, but on a good topographical map on a scale of 1 in. to the mile, the chalk Wolds and the western limestone ridges appear, with many variations of escarpment, valley, and other incidental features.

Where much of the surface is nearly level, as in the Fenland, there is little danger of the general effect of the map being obscured by crowded details of relief. In fact, the difficulty is to avoid omission of relatively low undulations and eminences, which, comprising more solid masses of gravel or other glacial deposits, formed the site of settlements when the surrounding fen was undrained marsh. The difficulty to some extent is overcome by adopting special contour intervals for such regions, but even then, features of some local significance may be omitted on the map. Again, a highland region of even moderate altitude may show considerable complexity of surface features which obscure a contoured map. This difficulty of overcrowding and obscuring relief features can be minimised by selecting a larger contour interval than the normal one.

Maps on a scale smaller than 1 : 250,000 (roughly 1 in. = 4 ml.) are not designated "topographical" maps, and are compiled where possible by reduction and generalisation from topographical maps (scales 1 : 250,000 and larger). Survey in the field is not as a rule carried out on scales smaller than 1 : 250,000. Maps on scales smaller than 1/M (1 : 1,000,000) are often designated atlas maps.

The accuracy, and with it the usefulness, of topographical maps, varies according to the methods employed and the conditions under which a survey was made. Surveys range from (1) the more informal and often rapid work of explorers and pioneers to (2) the more systematic work of geographical, military, or government surveyors under official and scientific auspices. The latter type of survey comprises (1) elaborate surveys carried out deliberately, according to a carefully arranged plan, and often extending over a considerable period; (2) more rapid, but carefully executed, surveys performed in connection with a Boundary Commission, or when two countries are mutually stabilising a common boundary;

(3) surveys executed on active service, frequently in undeveloped countries previously under native rule, and thus lacking reliable topographical maps.

The accuracy and usefulness of a topographical map will depend upon the accuracy of its primary framework. The primary framework should be split up into secondary and then detail inserted in the various component parts. By framework we here mean the fixing of points relative to one another, and not the graticule, which is the net on which they are plotted. If the framework of parts of the area be done separately and the results pieced together, there is likelihood of error, which can be minimised when the framework is made as a whole. Points which constitute the framework of a map's features may be determined by (1) **triangulation**; (2) **traversing**; (3) **astronomical observations,** and sometimes by combination of certain of these methods. Triangulation is by far the most accurate and scientific method, but sometimes relief and natural features render it difficult, and then other methods are employed. Land without hills is unfavourable to triangulation, and the type of country for which traversing may be preferable is forested lowland where well-defined landmarks are lacking. Astronomical observations give the least reliable data, but sometimes during expeditions are the only means possible.

2. PRINCIPLES UNDERLYING TRIANGULATION

The principle underlying triangulation depends on a fact which we learn from trigonometry, namely that if the angles and the length of one side of a triangle are known, the lengths of the remaining sides can be reckoned.[1] Triangulation consists in taking bearings of objects primarily from the ends of a carefully selected and measured base-line, and then building up a network of triangles, whence the name " triangulation." The apex of each triangle is a fixed point on the earth's surface, and if no convenient object for observation exists, the point must be suitably marked. Apices of these triangles are termed trigonometrical stations. If (1) at such stations horizontal angles have been observed to all other discernible stations around and if (2) the horizontal distance between two such stations is measured, it is obvious that other lengths represented by the sides of triangles can be calculated.

Official survey distinguishes various types of triangulation according to the degree of accuracy attained.

[1] Refer to page 160 on the theodolite.

3. TYPES OF TRIANGULATION

TOPOGRAPHICAL TRIANGULATION.—This is designed to give a framework accurate enough for a particular topographical map. Its object is rapid and cheap production of topographical maps frequently intended mainly to serve as a basis for plane-tabling detail on a relatively small scale, and nothing more accurate is desired than avoidance of error on that particular scale. For larger scale maps, or for extended work, such triangulation would not be sufficiently accurate.

PRINCIPAL TRIANGULATION.—Various technical terms are applied to more ambitious methods of triangulation. Principal (sometimes known as *Geodetic*) triangulation is very slow and elaborate, and necessarily expensive. Sides of triangles formed on this method by the British Ordnance Survey are about 35 ml. long, but in other surveys lengths considerably below or above this figure have been adopted. In this method the algebraic sum of the errors of all the angles of a principal triangle should not exceed one second.

MAJOR AND MINOR TRIANGULATION.—In Major triangulation an error of 5 seconds may be allowed, and in Minor triangulation the error allowed is 15 seconds.

SECONDARY AND TERTIARY TRIANGULATION.—Sometimes the sides of the principal triangles are subdivided to form smaller triangles. The methods are known as (1) Secondary Triangulation, where sides vary from about 5 to 10 miles, and where an error of 5 seconds is allowed. (2) Tertiary Triangulation, with sides from 1 mile to 5 miles, and error up to 20 seconds. In British Ordnance Maps the sides of Secondary and Tertiary triangles are about 5 miles, and rather more than 1 mile respectively.

The above details concerning the more elaborate methods of triangulation are of interest to students of geography, in so far as they show what care, time, and expense are devoted to surveys which produce large-scale official maps. There is no need at this stage to trouble about the technique of such surveys. Those who intend to specialise in Cartography as part of an Honours Degree Course, and others who are interested in the subject may consult the books noted on page 242, especially the official *Textbook of Topographical and Geographical Surveying.*

4. THE THEODOLITE

It is well here to note certain details concerning the theodolite, which is largely used for the framework noted in the preceding paragraphs.

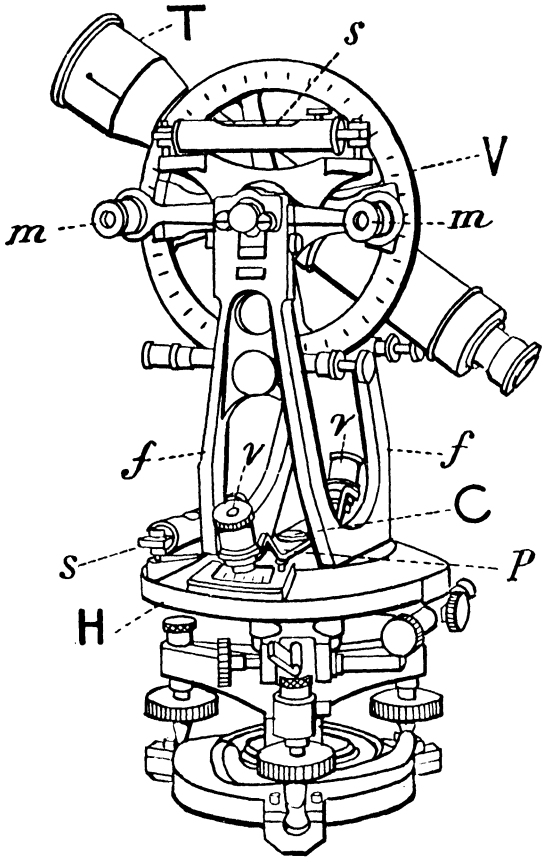


Fig. 83. TRANSIT THEODOLITE.

The theodolite (see Fig. 83) essentially comprises—

(1) A horizontal circular plate, H, furnished with two verniers, *v*, *v*, or with two micrometer microscopes 180° apart and graduated to read angles; a pointer P.

(2) A vertical circle, V, with two verniers, *m*, *m*, or micrometer microscopes, and graduated to read from 0° to 90° in one quadrant, 90°–0° in the next quadrant, etc. Graduations of a theodolite depend on the size of the instrument, and may be much more elaborate than those noted above.

(3) A telescope, T, which rotates about an axis passing vertically through the centre of the horizontal circle and capable of adjustment so that it can similarly rotate about an axis passing horizontally through the centre of the vertical circle.

Bearings for the telescope and the vertical circle are carried on frames, *f*, *f*. Spirit levels, *s*, *s*, are mounted on the horizontal plate and on the vernier arm of the vertical circle. The horizontal plate carries a compass, C, in its centre

between the supports of the telescope, and there is a screw to lift the magnetic needle off its pivot when not in use.

The theodolite is firmly screwed to a base or tripod, in the centre of which there is a hook from which to suspend a plummet in order to indicate the exact position where the station peg is to be driven into the ground.

Sighting is done through a telescope, because the theodolite is designed for long distance work. In the telescope is a diaphragm, finely etched with a vertical and horizontal line, kept in place by screws. Accuracy is ensured by these lines, the intersection of which should coincide with the object. The telescope is brought into focus by a milled screw near the object glass. There is a screw to adjust the axis of the telescope.

The character of parts noted above varies in theodolites by different makers, and according to the price of the instrument. Familiarity with the instrument can only come from actual use and demonstration by a competent surveyor. Reliable theodolites are costly, but smaller instruments embodying essential points which are sufficient to give a general idea of the principles involved may be obtained from various educational firms. Such model instruments are not intended for actual survey, and are less accurate than those used by surveyors.

The theodolite is used in triangulation (see Fig. 84), and for the determination of trigonometrical heights (see page 191). As regards function, it is a delicate combination of the prismatic compass and level, capable of very accurate readings. There is considerable difference in the measurement of horizontal and vertical angles. On the horizontal circle the difference in bearing between one point and another is measured; on the vertical circle the elevation of a point above the horizon is measured. Particularly in the latter case it is necessary to eliminate errors due to both instrument and observer.

Reference to diagram 84*a* will illustrate the principle of triangulation. Knowing base AB and angles *a*, *b*, it is possible to calculate BC; knowing BC by calculation and measuring angles *c*, *d*, it is possible to calculate CD and BD.

The principle of the use of the theodolite in triangulation can be seen if we imagine a triangle ABC representing an area in the district to be surveyed. The theodolite is set up at C, the telescope pointed on A and the reading of the pointer on the horizontal circle is noted. Still at C, it is next pointed on B and another reading taken. The difference between the two readings represents the angle ACB. The theodolite is moved to B, and the angle CBA is ascertained. Finally it is moved to A and the angle BAC is similarly determined. If the reading is

accurate, the sum of the three angles should be 180°, but if this is not the case, various adjustments are made.

It is necessary to measure one of the sides of the triangle, and given this side and two of the angles determined by the theodolite, it is possible by trigonometry to calculate the remaining two sides of the triangle.

Reference to detailed methods of survey by the theodolite are beyond the scope of this book. For such methods students are referred to the official *Textbook of Topographical and Geographical Surveying*, and to Hinks: *Maps and Survey.*

Here we are merely concerned with the theodolite as a means of making observations necessary in that survey which is the basis of large-scale maps.

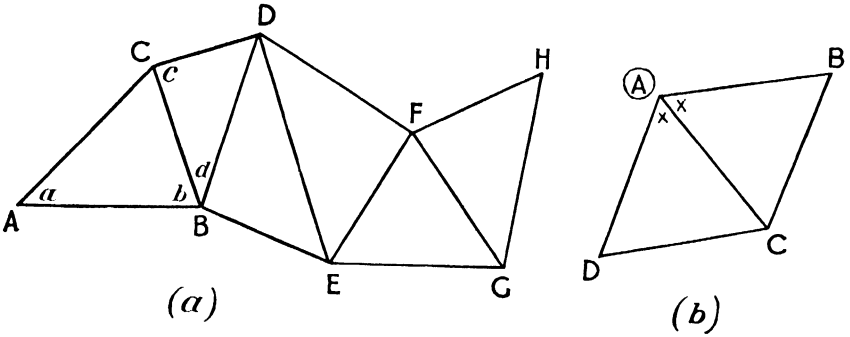


Fig. 84. Principle of Triangulation.

We are concerned with the principles rather than the details of such survey.

It is impossible to give theoretical directions for the manipulation of a theodolite. Familiarity with the instrument can only be attained by actual contact with a theodolite under the direction of a competent surveyor. There are several adjustments of screws and levels which cannot be mastered except by personal contact with the instrument. It is frequently used by surveyors, who are generally willing to give assistance to students for a reasonable fee.

Apart from refinements of adjustment, the following are some of the things to be noted in handling a theodolite.

It is centred over the station (A) (see Fig. 84*b*), where the angle is to be measured, and is carefully levelled. Adjustment is made for the vernier (reading index) or micrometer microscope. The instrument is turned until the telescope

Station (where theodolite is set up).	Point observed.	Face-left, swing right.		Mean.	Difference.	Face-right, swing left.		Mean.	Difference.	Mean Angle.	Name of Angle.
		Vernier I.	Vernier II.			Vernier I.	Vernier II.				
		° ′ ″	′ ″	° ′ ″	° ′ ″	° ′ ″	′ ″	° ′ ″	° ′ ″	° ′ ″	
A	B	31 37 22	38 18	31 37 50		211 40 10	41 30	211 40 50			
					66 58 10				66 50 58	66 54 34	BAC
	C	98 35 40	36 20	98 36 0		278 31 24	32 12	278 31 48			
					51 41 18				51 44 52	51 43 5	CAD
	D	150 16 12	18 24	150 17 18		330 16 4	17 16	330 16 40			
	B	31 37 18	38 12			211 40 24	41 25				

is aimed at the first point (B) to be observed. It is then focused. The telescope is now turned to observe the second point (C), and finally, the third point (D).

The first station should be the **back** station, and the second the **forward** station, that is, the station where you will next go with the theodolite. Thus, the angle is always measured clockwise from the back station to the forward.

Errors are minimised by reading each angle twice, the telescope being turned round vertically after the first reading. If the vertical circle is first on your left as you use the telescope, it will be on your right after the telescope is turned. The reading is said to "face-left" or "face-right," as the case may be, and is entered thus in the angle-book. After centring, levelling, and setting to magnetic north by means of the compass on the theodolite, the telescope is set so that the vertical circle is on your left (face-left). The telescope is focused on each station in turn, and is swung from station to station in a direction from left to right. Both verniers are read and the readings are entered in the angle-book as "face-left, swing right" readings.

The telescope is now swung over vertically and the stations are read from right to left. Results are entered "face-right, swing left."

In the angle-book, **degrees** are entered for one vernier only, **minutes** and **seconds** being sufficient for the other. See page 159 for limits of error allowable.

Specimen angle-book entries are given in the table on this page. The student should also refer to Fig. 84*b*. The entries are similar to those advised by Professors Jameson and Ormsby in their *Mathematical Geography*.

The difference given in columns six and ten of the table is found by subtracting the first mean from the

second, and so forth. This difference[1] gives the **angle**, and the mean values for the angles under (*a*) face-left, swing right, and (*b*) face-right, swing left, gives a final mean for the respective angles. If there is much discrepancy between this and either of the "differences," something is wrong, and the readings had better be made again. As a further check a reading is taken on station B.

5. THE MAPPING OF AN ISLAND

Map-making on a fairly large scale can be illustrated by describing the survey of an island not previously mapped. First make a preliminary rough survey or reconnaissance. Points would be selected (1) for base, from which to commence observation; also for check base; and (2) the trigonometrical stations, that is for the apices of triangles in what is known as triangulation. (See page 161.) These stations are prominent features such as hill summits or prominent points on plateaux, cliffs, etc. They may be as much as 20 or 30 miles from the base and from subsequent observation points. When the stations are thus far apart, beacons are set up on them to aid observation. In the preliminary observations a rough diagram is made to show the relative position of the stations. This done, the actual surveying is begun.

First we measure the base, which should not be less than a mile in length. It is best measured by invar tapes along the ground, or, better still, suspended from trestles. Corrections are made, such as (1) to counteract any variations due to temperature changes in the tape, or (2) to adjust any defects in alignment, etc. Such a base, say a mile long, should be measured within one-tenth of an inch, because errors in initial base measurement lead to considerable inaccuracy in the actual triangulation.

When the base, I (see Fig. 85), has been measured, it is extended by triangulation. A theodolite is used and is centred over one end of the base. Angles to the points chosen for base extension are measured, and the base extension is completed to points *a* and *b*. From *a*, angles to various points fixed by beacons are observed, and the same is done from *b*, the stations *c*, *d* being fixed. The side *bc* acts as a base for fixing *e*; *be* as a base for fixing *f*, and so forth, until the triangulation is complete.

A second base, II, may then be measured to check the work by comparing its measured length with its length as computed by the triangulation.

[1] Reason is apparent, for the observations are *bearings*.

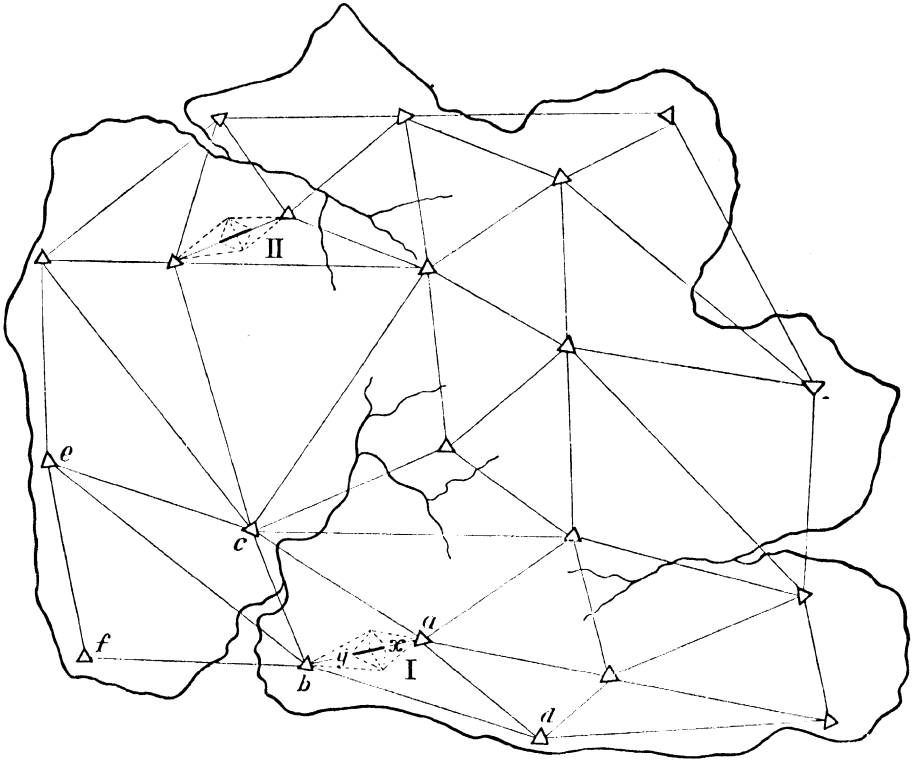


Fig. 85. Triangulation of an Island

Note :—This triangulation gives the area of the island and the position of prominent features. Some method of determining the heights of relief features is necessary. Before the actual survey it will be necessary to determine mean sea-level by taking the average of a series of observations showing the mean between high and low water level for a considerable period at a given place. Then the height above sea-level of one point in the triangulation can be definitely fixed by levelling or triangulation.

By means of the vertical circle of the theodolite, the difference in height between the different trigonometrical stations is ascertained at the same time as the horizontal angles for triangulation are read, and thus the heights of the various stations can be recorded.

To fix the position of the island on the globe, the latitude and longitude of one point, say the end of the base, would be determined by astronomical observation. Further astronomical observation would give the true bearing or "azimuth" of the base, and would thus relate the triangulation to True North.

By use of the plane-table (see page 169), detailed information can be inserted in relation to the trigonometrical stations, and thus the basis of a topographical map is built up. Where triangles are not shown on Fig. 85, minor triangulation and plane-tabling might be used.

CHAPTER XV

PLANE-TABLING

1. EQUIPMENT

The following are the essential parts of the equipment for plane-tabling:—

(1) The plane-table and its tripod.

(2) A measuring tape or chain.

(3) A box-compass, otherwise known as a trough-compass.

(4) An alidade or sighting-rule, and a spirit level.

(5) Two or three sighting-rods about the size of a cricket stump for marking stations where the plane-table is set up, and a few longer rods for sighting purposes when there is no convenient object in the landscape.

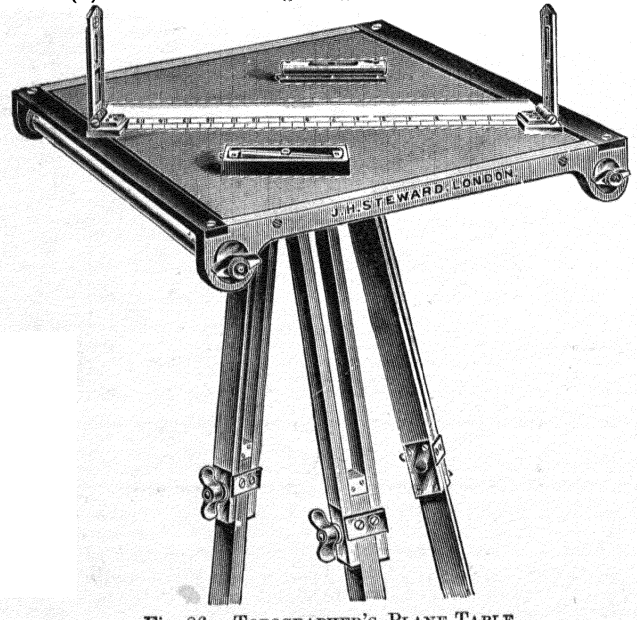


Fig. 86. TOPOGRAPHER'S PLANE-TABLE.

(6) A pair of serviceable field-glasses for distinguishing and identifying distant objects and features.

(7) Paper and sundry accessories for drawing, such as pencils, rubber, drawing-pins, a penknife or razor-blade pencil-sharpener, a protractor marked with scales if the alidade is not thus graduated.

The **plane-table** (see Fig. 86) is a portable table supported on a tripod: the top can be revolved or fixed in any desired position in a horizontal plane; hence the name.

The table-top is essentially a drawing-board, varying in size from about 15 in. by 10 in., or 15 in. square, or 18 in. by 12 in., to 18 in. by 24 in., which is

a large size. The top of a good table has a sunken brass rim for tightening the paper. There must be nothing projecting *above* the surface of the table, and drawing-pins, if used, should be fixed underneath, though there are other more desirable means of fixing the paper. Below the table-top is a pivot-plate of brass let into the drawing-board and fashioned in such a way that it will take and hold the head of a bolt in the tripod block. It is important that the metal fittings of board and tripod be other than iron or steel, which would affect and render the compass inaccurate.

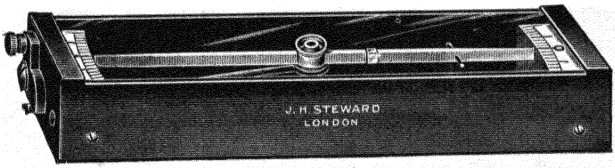


Fig. 87. METAL TROUGH COMPASS.

The tripod should not be more than about 4 ft. high when in position. The legs are hinged to a wooden block, and usually have fly-nuts at the sides to facilitate tightening. Telescopic legs are not favoured by many good plane-tablers

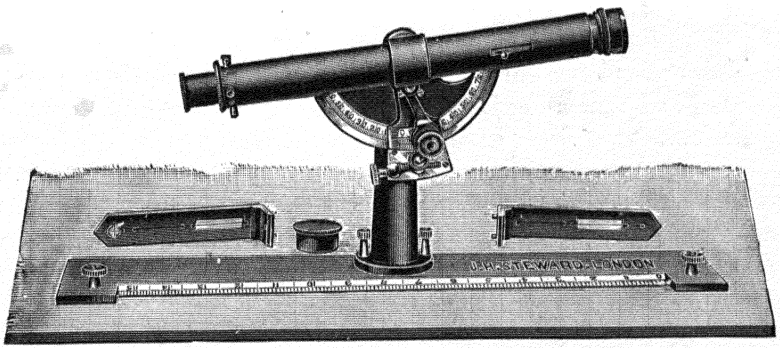


Fig. 88. ALIDADE WITH TELESCOPE.

because they cannot be relied upon for rigidity, a most important essential for securing accuracy. On the tripod head, in the centre, is a thumb-screw designed to fit into a socket on the lower side of the drawing-board.

The **box-compass** (Fig. 87) is designed to enable the plane-tabler to draw on the paper a line parallel to the compass needle at rest. The compass comprises a magnetic needle about 5 in. or 6 in. long, and mounted on pivot in an oblong box with parallel sides and glass lid. The best compasses have arcs at

each end, graduated to show sufficient degrees of the circle to facilitate coaxing the compass to indicate north.

The **alidade** (Fig. 88) is a strong, flat ruler, 12 in. to 18 in. long, and is usually made of box-wood or other hard wood. At each end it has flap-sights which can be raised or lowered at will. One of the sights has a thin, vertical hair or wire down the centre, such wire being aligned on the object sighted. The other sight has a narrow vertical slit down the centre. It is important that wire and slit be exactly in the centre of the ruler, or accurate sighting cannot be guaranteed. The edge of the alidade may be graduated like an ordinary ruler, or it may be marked with scales, such as 8 in. to 1 mile. It is well if the alidade is fitted with a spirit level. If this is not the case and if the drawing-board is not so fitted, a separate spirit level must be used. For very particular work, telescopic alidades are procurable. They comprise the usual ruler which, in place of the sight-vanes, carries a telescope with cross-wires on the object lens. In some telescopic alidades the telescope may be removed and the ruler used with sight-vanes.

2. METHOD OF PREPARATION

Before attempting practical work, see that the table and tripod are in good working order, and that all adjustments can be made easily, *e.g.* levelling and clamping the table-top. Next carefully prepare the paper. In more rough and ready work or for practice the drawing-paper may be fastened directly on the drawing-board. This is not recommended for the best type of work, but if done, the paper should be folded over and pinned *below* the board.

A better method is to use a thin, flat board made of some strong wood which will not warp readily, and corresponding with the area of the table. On this thin board stretch some linen somewhat larger than the board and with sufficient edge to overlap the plane-table. Before it is stretched on the board, the linen should be well soaked. Place the board on the plane-table, linen side uppermost, then turn over and paste the loose linen edges on the underside of the table. Damp and carefully paste a sheet of drawing-paper on the linen, smoothe the paper to prevent creases and wrinkling, fold over the edges and pin securely on the under-side of the plane-table. If the mounting has been properly done, the paper has a beautifully smooth surface, and the drawing can be readily made, especially as regards accuracy of angles where rays intersect. The result well repays the trouble taken in preparing the paper, though, for practice, students

may prefer the method entailing less preliminary preparation. However, it is well to try the more elaborate method in order to master the details.

Cultivate the habit of setting up the table with reasonable quickness and without fumbling. If you have trouble with the apparatus, you may turn out less careful work. The top must be level, and for this the spirit level is essential. At first see that the legs are screwed to the block sufficiently loosely to give them free play. Hold a leg in each hand and, as it were, throw the other leg outwards from the table, at the same time putting the two held legs on the ground. Practice with this method should result in a fairly level table-top, and adjustment can be made with the aid of the spirit level. Be careful to screw up the fly-nuts of the legs securely. If you are working on a slope, two legs of the tripod should be down the slope and the other up it. Whether on the flat or on a slope, do not have the table too high. If adjusted a moderate height, it is easier to sight from it and to draw on it, and there is less likelihood of the table being blown over. Such an accident would necessitate re-orientation of the table, and the drawing would not be improved by coming in contact with wet or muddy ground. Avoid knocking against the tripod legs or in any way shaking the table.

It is obvious that the assumed position on the paper should be centred over the actual station on the ground. To test that this is done approximately, a long fork with a pointed arm is sometimes used to fix on the station's position on the board. Another fork fitted with a hook to carry a plumb-line is fixed below the table beneath this point, and the plumb-bob should be immediately above the station on the ground. In practice this is hardly possible unless the station is in the centre of the board, because the turning to orient the board after it has been centred and levelled, throws out the centering somewhat. Such error is small if the centering has been reasonably correct.

3. PROCEDURE IN THE FIELD FOR SKETCH MAP DEPENDING ENTIRELY ON PLANE-TABLING

Having prepared the drawing-board and paper, and being sure that the apparatus is in good order and that you can set it up properly, select a **base,** or a position for making a start. A good base may be central as regards the area to be mapped, should be on reasonably level ground, should give a clear view of the country from each end, and each end should afford a sight of a few prominent landmarks. From half a mile to one mile may usually be regarded as a suitable length.

If the base is not central, some of the stations observed and fixed may be too far away to ensure accuracy, and certain rays will come out awkwardly when intersecting others. On level ground, measurement of the base can be made more readily and more accurately, and such measurement must be as accurate as possible with a view to proper determination of scale. As the map is made from the base, it is obvious that it cannot be properly made if the country and its chief landmarks are not readily visible. The great point about extension from a base is selection of stations and shape of extension triangles. These should be as nearly equilateral as possible. It is not always essential that the base should be central. For ordinary mapping half a mile would not be an unduly long base. A very accurate extension can be made from a one-mile base, whereas it is not easy to measure a longer base, or to find level ground in hilly country for a longer base.

The base being selected, set up the plane-table at one end of the base, and use the spirit level to ensure that the table-top is in a horizontal plane. The table is levelled by moving the legs of the tripod or by means of levelling screws, such screws being attached to the better-made tripods. Place the alidade on the paper so that its edge coincides with the base-line, and turn the board so that the sighting-wire cuts the marking pole set up at the other end of the base. Clamp the table, and make a small dot to represent the end of the base where the table is standing. Put a small circle round the dot to assist legibility and mark it " I " to represent the first station on the base. Some plane-tablers fix a pin vertically on the dot, take the alidade and pivot its edge against the pin, next aligning the sights on the sighting-rod which indicates the other end of the base. This is done by placing the eye behind the slit and fixing the hair-wire to coincide with the rod. The ruler is kept firm and a line is drawn along its edge. This line represents the base-line and should be marked " Base."

The official *Textbook of Topographical Surveying* deprecates the use of pins. It advises that when a ray is to be drawn from any point, the pencil should be held upright with its edge touching the point, and that the alidade should then be pivoted against the pencil.

Next select the stations which you wish to fix, and, carefully keeping the table in position, pivot the ruler on end I of the base-line, and draw a line in the direction of each object which you intend to fix on the paper. Such lines are known as **rays.** It is well to identify each station by name and to write this along the ray. (Fig. 89.)

When all the required rays have been drawn, fix a sighting-rod in the ground to coincide as nearly as possible with representation of base-end I on the drawing-board. Move the plane-table to the other end of the base, measuring the distance between the two base-ends by chain or by pacing. At the second end of the base set up the table approximately, unclamp it, and on the line previously drawn to represent the base, bearing in mind the scale to be adopted, show position of base-end II by means of a dot and small circle as before. It is important that the base-line be drawn carefully to scale, because it is the foundation of the scale of the whole sketch. Pivot the ruler on end II of the base-line, lay it along the base-line, and revolve the board gently so that the hair-wire coincides with the sighting-rod left at station I. Clamp the table, which is now duly set or **oriented.**

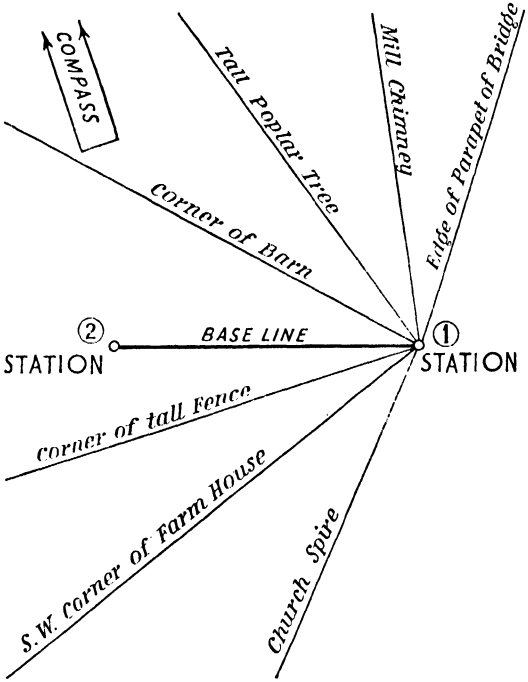


Fig. 89. PLANE-TABLING. GRAPHIC TRIANGULATION. First Stage. Set by (1)-(2).

With the ruler pivoted against the pencil, draw rays from II towards each of the stations to which rays were drawn from I. (Fig. 90.) Put a small circle round each intersection of rays and write the name of the station near its circle. If desired, simplicity can be secured by rubbing out the rays, leaving nothing on the paper except the intersection of the rays and the base-line.

Before leaving the base-end I, it is well to find North. Lay the box-compass on the paper, say, on the top left-hand corner, and slowly turn it round until the needle comes to rest with its north and south points exactly coinciding with similar points marked on the bottom of the box. Rule a line along the edge of the box, indicating north by an arrow-head. This line is the magnetic north-south

line. A similar line can be drawn parallel to it along the other edge of the compass, which can easily be fitted between these parallel lines when re-orientation of the table is desired. After reaching the base-end II. the orientation of the table may be checked by laying the box-compass between the north-south lines and watching the behaviour of the needle. If there is any great deviation, error has probably been made in taking a sight of base-end I from base-end II, and, after unclamping the table, you can gently revolve it until the needle and the north-south line on the paper coincide.

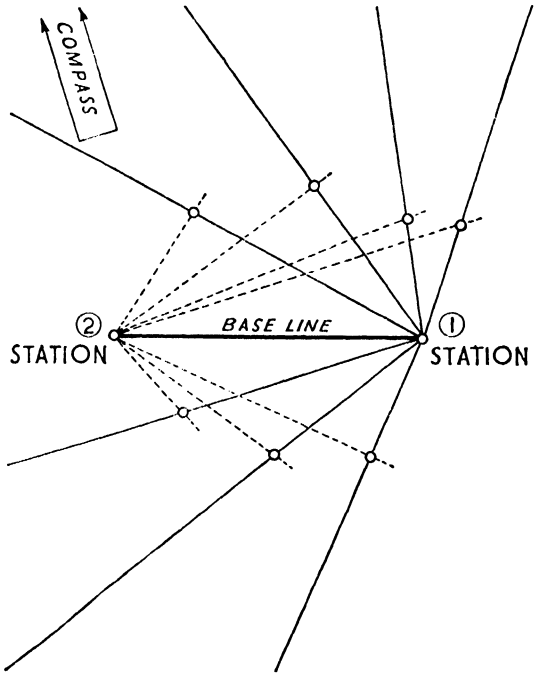


Fig. 90. PLANE-TABLING. GRAPHIC TRIANGULATION. Second Stage. Set by ray (2)-(1).

The sketch can further be extended by going to one of the stations where rays intersect, and by setting the table on a base-end by means of back-ray reading, that is, by aligning the sights of the alidade along the ray until the hair-wire coincides with the sighting-rod at the base-end. (Fig. 91.) Setting can also be done here with the compass, or it can be used as an additional check. Setting being achieved to your satisfaction, next work from the intersection of rays representing your new position and proceed to draw rays to fresh stations. A fourth station may similarly be selected, and rays drawn from it to intersect those drawn from plane-table station III. If rays can be drawn from either of plane-table stations III or IV to the intersection of rays from stations I and II, the three rays may not intersect, but will form a triangle. This is known as the **triangle of error**, and its centre can be taken to indicate the station in question if the triangle is small. If it is large, some error probably has been made in

sighting for one of the rays or in setting up the plane-table at one of its stations. Such a method can sometimes be used as a check, and if any serious discrepancy results, the work can be gone through again until the cause of the error is located. Such a contingency, however, should not occur if the work has been performed with reasonable care. When all the necessary rays have been drawn, the frame-work of the sketch is completed. The base and the various observed stations are in position relative to one another and to the magnetic north-south line.

Now rub out all unnecessary lines, merely retaining intersections of rays and the base-line, and clean up the paper as well as possible. It is ready for insertion of topographical detail. Sketch in such features as streams, canals, woods, hedges, houses, churches, roads, railways. If discretion be exercised in selecting stations for intersection of the rays, they will assist compilation of the sketch. Good stations are ends of bridges, corners of woods or buildings, church spires or towers, windmills or water-pumps, prominent trees, corners of fields. Sometimes, as in very flat country with few landmarks, it may be desirable to set up sighting-poles to mark stations. In the preliminary location of stations, use should be made of a good field-glass, and in bright sunshine tinted spectacles may help such location, as well as the drawing of rays. Before final choice of stations, a preliminary reconnaissance with the field-glass from base-end I is preferable to haphazard taking of stations as you proceed.

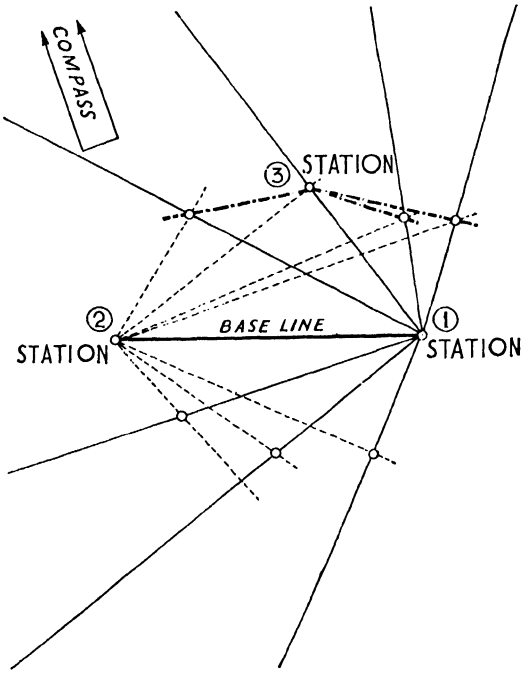


Fig. 91. PLANE-TABLING. GRAPHIC TRIANGULATION. Third Stage. Set by ray (2)-(3).

The method just described is known as **Graphic Plane-Table Triangulation,** and consists in filling in the framework as well as the detail with the plane-table at one and the same time. The basic idea is to fix a sufficient number of stations to give a framework or skeleton for the detail, and the principle is the same as for triangulation with theodolite or prismatic compass. Triangulation by plane-table lacks the accuracy of careful triangulation by theodolite, and there is much less mobility and speed than when a prismatic compass is used. However, by means of the plane-table it is possible to secure a reasonably accurate sketch-map of a small area. If there has been no previous trigonometrical triangulation, and if the plane-table survey is the first to be made, it is obvious that one important essential of a topographical map is lacking, namely, indication of relief. Therefore, to make the sketch complete, some method of contouring is necessary. (See page 198.)

4. ANOTHER USE OF THE PLANE-TABLE

Another use of the plane-table is to *fill in detail* when certain framework points, known as *trigonometrical stations*, have been fixed by the theodolite.

In its essentials, the method is similar to that previously described. The table and its accessories are similarly prepared and adjusted. First take up position at one of the stations previously fixed by theodolite, and set up the table on the mark indicating the station. Unclamp the table and lay the alidade on it to coincide roughly with a line joining the first with any other known station, the hair-wire being nearer the more distant station. Unclamp the table and revolve it until the alidade is sighted on the distant station. Now clamp the table, and, using the compass as directed for Graphic Triangulation, fix the north-south line. The north-south line is used for setting the table when moved to the second or any subsequent station. These two stations first selected serve the same purpose as the ends of the base-line in Graphic Triangulation. As in this method, prominent objects are selected as stations, and rays are drawn to them. Rays should not be drawn haphazard, and it may be found convenient to draw rays in succession clockwise from the station where the table is located. Rays should be drawn to objects which can serve as landmarks when inserting detail after all the stations are fixed. Detail should not be inserted by guess-work or approximate estimation, but short rays should be drawn to indicate the relative direction of trees, buildings, etc.

5. DETERMINING POSITION BY RESECTION

By means of a method called **resection,** the principles underlying plane-tabling can be used to determine one's position. We set up the plane-table and align the sight-rule on certain selected distant objects. Rays are drawn backwards from these objects to the observer, whose position is indicated by intersection of the rays.

Select three objects in the country which you can identify on the map. Set up the plane-table, orient it, and fix the map on the table. Draw rays from objects in the country through their counterparts on the map and towards yourself. If these rays intersect at a point, this is your position. In practice it is possible that they will not intersect, but will form a triangle known as the "triangle of error." This error may be due to faulty setting of the plane-table or to defects in the compass.

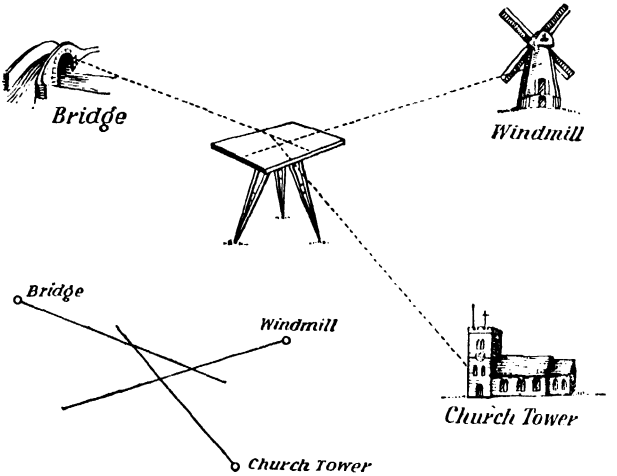


Fig. 92. Triangle of Error.
With observer's position inside the triangle (see also Fig. 93).

The three objects should be selected so that they and you will *not* be on the circumference of a circle. It is advisable, if possible, to select objects so that you are within a triangle formed by imaginary lines joining the objects.

If you can select the objects so that you are inside such a triangle, you are inside the triangle of error. (Fig. 92.) If you cannot so select them, you are outside the triangle of error. (Fig. 93.)

Your position can be estimated approximately. If you are inside the triangle of error, the distance of such position perpendicularly from any ray is proportionate to its distance from the object from which the ray was drawn. If you are outside the triangle of error, your position is either to the right or the left of all the rays as you look towards the three objects in the actual country.

To test whether you are to the right or the left of the rays, slightly turn the table-top, say, to the left, and draw new rays from the three objects. If the triangle of error resulting from the new rays is smaller than the first triangle of error, your position *is* on the left of the rays. If the new triangle is larger than the first one, you are *not* on the left of the rays but on the right. The rays make six sectors, but your position can only be in one or two, either 3 or 6, *i.e.* either to the right or left of the rays. Having determined as directed above whether you are to the left or the right of the rays, it will be at either x or y. (Fig. 94.)

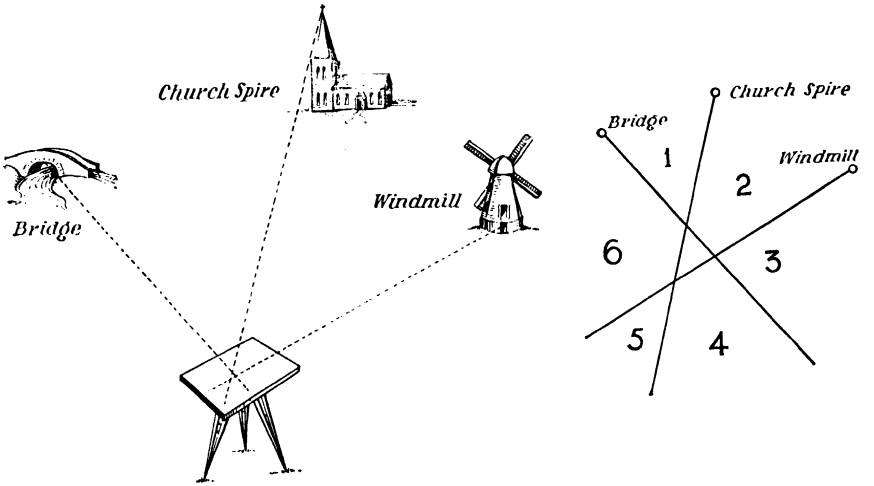


Fig. 93. TRIANGLE OF ERROR.
With observer's position outside the triangle (see also Fig. 92).

Lines drawn from x or y at right angles to the rays are in proportion to the distance from x or y to the objects from which the rays are drawn.

To check the solution of the triangle of error, *i.e.* to check your estimated position, pivot the alidade against the estimated position on the map, and direct it on the ray from one of the objects. If the latter is off the sighting-wire of the alidade, unclamp the table and revolve it until the object is properly sighted. Then clamp the table and draw a fresh ray. Complete the resection for the other two objects if the rays do not meet at a point, and you ought to have a much smaller triangle of error. If the triangle is larger, there is something radically wrong with your solution, and the whole operation should be done again, care

being taken to see that the ruling points, *i.e.* the objects sighted, have been properly sighted and set down.

Plane-table surveys are generally made between triangulation stations, which are points whose relative positions have been fixed by means of a theodolite. (See page 161.) Such fixing is very accurate, and therefore triangulation stations form a suitable framework for plane-table survey. The distance between them is not so great that serious error is likely when you are working from one such station to another, and is usually about a mile.

Triangulation stations might be used as the ends of a base-line, and from them intersecting rays could be drawn to new stations as explained on page 171. This method, however, is not so convenient or so speedy as to select a station, to set up the plane-table at it, and to fix its position on the map in relation to any three triangulation stations without taking the plane-table to these stations and then bringing it back.

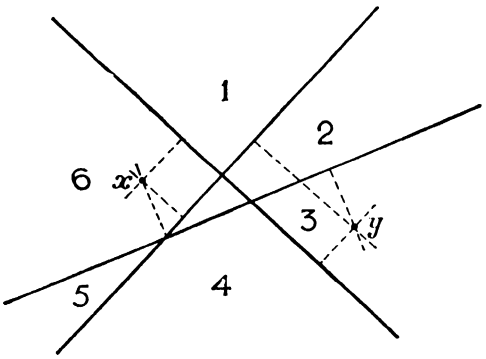


Fig. 94.

Such fixing on the map of the position of a new station by making observations from it to known stations is an application of the method of resection explained above, and is adopted in plane-tabling when sufficient trigonometrical stations are available.

6. DETERMINING POSITION BY ADJUSTMENT

Fix a piece of tracing-paper to the drawing-board with drawing-pins. Select three objects in the country which are shown on the map. Mark a dot on the paper to represent your position. From the dot draw rays directed on each object, and write their names on the appropriate rays. Unpin the tracing-paper and place it on the map, revolving the paper until each ray passes through the object on the map corresponding to the real object from which such ray was drawn. Re-pin the paper on the map, prick through the point of intersection of the rays on the tracing-paper, and your position on the map will be where the pin-prick touches it. If the rays do not intersect, prick through the approximate point given by solution of the triangle of error.

CHAPTER XVI

TRAVERSING

1. INTRODUCTORY

The essentials of a **traverse** are a series of connected straight lines, making various angles, the lines and their included angles being derived from measurements with certain instruments. Angles are determined by taking bearings upon various objects with theodolite, prismatic compass, or plane-table. Lines result from measurement with a chain, use of a cyclometer, passometer, or pedometer, or by simple pacing. A traverse sketch can be completed in the field, or the observations can be taken, entered in a field-book, and the actual drawing done indoors.

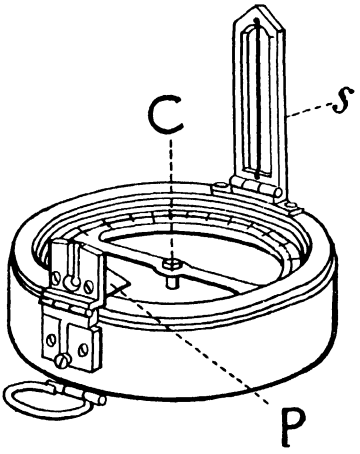


Fig. 95. PRISMATIC COMPASS.

For accurate map-making, triangulation is much superior to traversing, but the latter is useful (1) in flat and densely forested country where the sighting of trigonometrical stations is difficult, and, for similar reasons, in towns; (2) when speed, mobility, and portability of instruments is desirable. When the last-named consideration is important, the prismatic compass is convenient.

2. THE PRISMATIC COMPASS

The **prismatic compass** (see Fig. 95) is a circular magnetic compass, to which on one side there is fixed a prism, P, with a slit in it, and on the other side a sighting-vane, *s*, containing a hair-wire. An imaginary plane from the prism-slit to the hair-wire passes through the pivot-pin, which is the central point, C, of the compass. This makes for ease and accuracy in reading the bearings of objects sighted, because the surveyor can read the bearing without taking his eye from either sights or object sighted. This is because the prism enables the eye to see the figure just beneath it on the card. For this to be possible, a prismatic compass is graduated

the opposite way to an ordinary prismless magnetic compass. That is, 180° is shown over the North end of the needle, and 360° over the South end.

There are several types of prismatic compass, but the principle of using them is the same. The compass should be held firmly between the thumb and fingers of the *left* hand, one finger being conveniently near the check-stop, which is used for bringing the card to rest. The compass should be held so that the card is in a horizontal plane and so that the prism faces you. Use the thumb and first finger of the *right* hand to steady the compass, grasping the rim for this purpose. The prism and sight-vane of course should be raised before the compass can be used. It is used by closing the left eye, and looking through the prism-slit with the right eye, the hair-wire being aligned on the object whose bearing is desired. It is important to align the sight on the centre of the object, and to stand so that you are facing the latter squarely. Should the card swing too much, make use of the check-stop, and when the card is at rest, note the figure which is in line with the hair-wire and the observed object. This is the bearing required.

The method of using the prismatic compass seems simple when thus described, but considerable practice is necessary before facility can be attained. It is very important (1) to keep the compass card in a perfectly horizontal plane to prevent the edge of the card coming in contact with the glass lid and being unnaturally checked; (2) to stand squarely as directed so that accurate alignment of the sights can be made; (3) to keep the compass as steady as possible, so that the card may have natural play.

In a "liquid" prismatic compass the needle comes to rest more rapidly. The graduated aluminium ring which is attached to the magnetic needle is completely immersed in a non-freezable liquid in which it floats, and is thus kept very steady and free from troublesome oscillations. The ring comes quickly to rest, and a series of bearings can be taken in much less time than with an ordinary prismatic compass. If the compass is used on a stand, greater accuracy results.

Reference is made to page 14, where **bearing** is explained.

The chief advantage of a prismatic compass is that it is portable, and considerably more so than the plane-table, which, however, is much more accurate than the compass. A good prismatic compass is expensive, and certain errors are incidental to it, so that its accuracy may be impaired. It cannot be used in the vicinity of iron, as the needle is then affected and ceases to be a true guide to the North. Hence observations cannot be made near iron bridges, railway lines, railings, etc.; and rocks containing iron-ore may be a serious inconvenience.

3. TO MAKE A FIELD-BOOK TRAVERSE WITH A PRISMATIC COMPASS

The **field-book** is an ordinary notebook, with pages as long as possible compatible with reasonable ease in handling. Vertically down the middle of each page are ruled two parallel lines half to three quarters of an inch apart (see Figs. 98 and 99). This column is known as the **chain column**, and its purpose is to contain entries relative to the main line of the traverse. It serves to keep the entries clear of those in the **offset columns** on each side of it. In the chain column are entered as they are ascertained (1) the number of the traverse station, (2) the forward bearing read from the prismatic compass, (3) the distances measured or paced from station to station. Entries are begun at the bottom of the last page and work upwards on the page, this procedure being repeated when a fresh page is started. This ensures that the chain column always points in the direction in which you are moving when making the traverse.

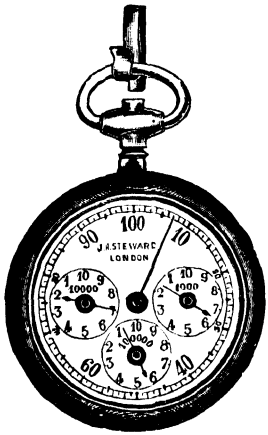


Fig. 96. PASSOMETER.

Having selected the station from which to begin, make in the chain column a dot with a small circle round it as you would do at the end of the base-line in plane-tabling. This symbol will indicate your traverse station. Write the Roman numeral "I" near it, indicating and numbering subsequent traverse stations to correspond. Suppose you are traversing a road or route; with the prismatic compass take a forward bearing to where the first change of direction occurs, write the number of degrees, with the appropriate degree symbol, above the station mark in the chain column.

Before you leave this station, look on either side of the route for conspicuous objects within a range of, say, half a mile or more. Take the bearing of such objects, drawing in their approximate direction a line from that border-line of the chain column which is nearer the objects. Write along these offset lines the bearing of the object concerned and a name for subsequent identification. A second bearing on these objects must be taken from another point along the traverse. One bearing on an object would give direction only. If only one bearing were used, it would be necessary to measure a chain distance along the first bearing in order to fix the position of the object.

Proceed along the traverse direction, pacing or measuring as you go, and look carefully on each side of the traverse for other offset objects suitable for bearings. See Fig. 96 for Passometer, which registers paces, and Fig. 97 for Pedometer, which registers miles or fractions of a mile (*i.e.* 80 yds.) traversed. When you see a suitable object, halt and enter in the chain column the distance from the last station. Take the bearing of the offset object now noted, make entries of bearing and name as before, and again proceed. When the next change of direction occurs and a new forward bearing is necessary, draw a line across the chain column, and above this line indicate and number a new traverse station. Below the line should be entered the distance from the last station and not from the last intermediate stopping place

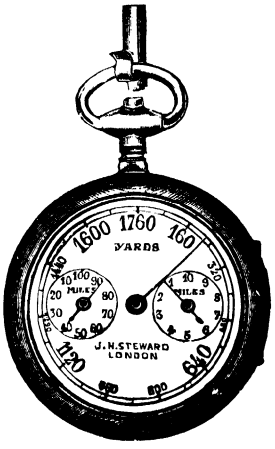


Fig. 97. PEDOMETER.

The procedure is the same until the last station has been reached. The method is easily understood. It may be helpful, as a preliminary exercise in order to gain familiarity with the field-book, to make entries of an imaginary traverse, the details of which can be pictured mentally. Better still, if you know anyone who can traverse, persuade him to go out with you and make a short traverse. Watch him carefully and try to apply our hints to his methods. Before actually attempting a traverse, it may be helpful to obtain preliminary practice in using a prismatic compass. Bearings (forward) can be practised almost anywhere and sometimes a check can be made by means of back bearings. A geographical student should attain reasonable facility in using instruments for the simpler types of surveying, but he is not expected to do practical work with the skill and precision of a trained surveyor. However, for the various examinations where inspection of the original note-books is demanded, there is necessity for (1) reasonable accuracy; (2) neat work; (3) acquaintance with the usual technical methods employed in survey work. This particularly applies to such work as field-book entries for traversing and their subsequent plotting into diagram form. The plotting is done indoors, and if this final work can be undertaken as soon as possible after the field observations, details of the actual country will be remembered more readily and the plotting will thus be easier.

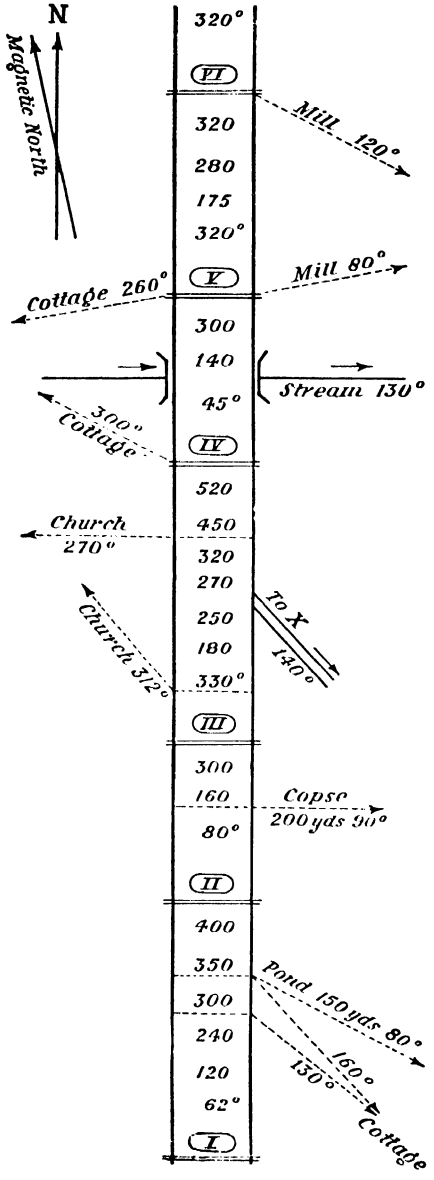


Fig. 98. Field-Book Entry.
Traverse of a road.

		125 yds
Pavilion corner	q	98°
Pavilion corner	p	89°
Path corner	c	74°
		105°
		V
		175 yds
Path corner	c	194°
		207°
		IV
		110 yds
Path corner	b	222°
		247°
		III
		175 yds
Path corner	b	301°
Path corner	d	275°
Pavilion corner	n	253°
Path corner	a	271°
Pavilion corner	m	245°
		332½°
		II
		150 yds
Pavilion corner	q	330°
Pavilion corner	p	343°
Path corner	a	48°
Path corner	d	0°
Pavilion corner	n	13°
Pavilion corner	m	40°
		60°
		I

Fig. 99. Field-Book Entry.
Closed traverse of a small park.

For plotting the bearings, which result from angles, a protractor is required, and paper with parallel lines to serve as Magnetic North-South lines for plotting the bearings. They are termed zero-lines. Drawing paper can be prepared with such lines lightly pencilled and they are generally most convenient when they coincide with the direction of the longer side of the paper. It is well to place an arrow-head at the end of one of these lines to represent Magnetic North.

4. PLOTTING BEARINGS FROM A FIELD-BOOK

To plot the first bearing (see Figs. 100 and 101) entered in the chain column of your field-book, make use of the protractor with reference to one of the zero-lines. Lay the protractor on the paper for the ungraduated side to coincide with or to be parallel to one of the zero-lines, and if the bearing is between 0° and 180°, have the graduated side to the right of the zero-line. If the bearing is between 180° and 360° see that the graduated side of the protractor is on the left of the zero-line.

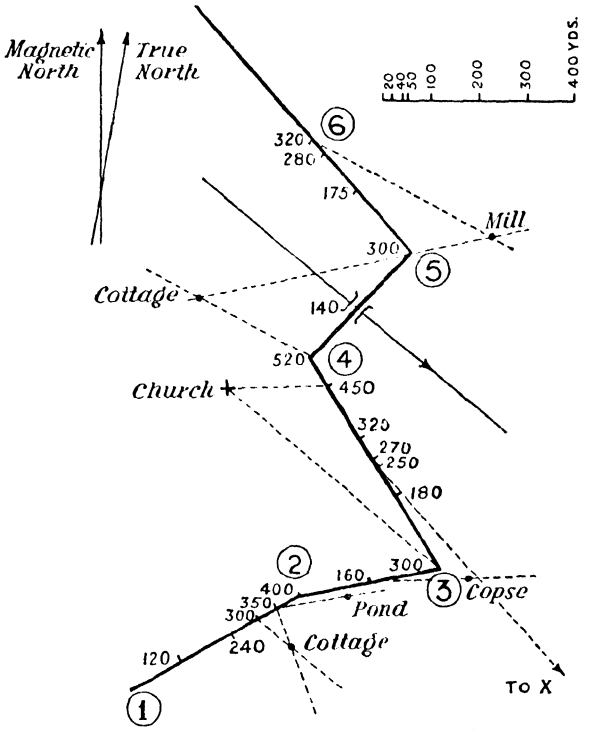


Fig. 100. Plotting of Field-Book Entry. Plotted traverse of a road.

Mark with a dot on the paper the central part of the ungraduated protractor edge (shown by an arrow on the service protractor, and by the end of the 90° perpendicular line on the semi-circular pattern). Mark with another dot on the paper the position on the graduated edge of the protractor of the number of degrees indicating the bearing to be plotted. Remove the protractor, and draw a straight line from one dot to the other, and this, with reference to the zero-line, is

the bearing of the required object drawn from the point where it was observed. This point is represented on paper by the dot coinciding with the centre of the ungraduated edge of the protractor. This bearing represents the first stretch of route before change of direction. On it, according to the scale selected for the sketch, mark off the relative length between the first two traverse stations.

Offset bearings are plotted similarly, but care must be exercised to get, on the forward bearing from the first traverse station, the point from which the offset bearing was taken. This is only a matter of noting how far such point is from the first station and adjusting the scale accordingly.

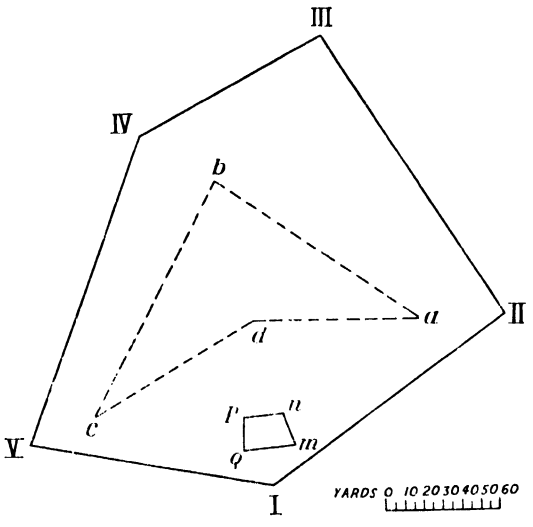


Fig. 101. Example of a Closed Traverse Plotted. Bearings were plotted as in Fig. 100, but rays are not shown in the diagram.

The rest of the traverse is similarly plotted, and there should be little difficulty once the principle is understood. Considerable practice is necessary before facility can be expected. It is useful to make a few field-book entries for a short imaginary traverse and to plot them. In such exercises the knack of forming mental images is helpful. For instance, try to visualise the making of a traverse represented by your imaginary field-book entries, and before you begin plotting try to visualise the sketch, or at any rate part of it, as it should appear on the paper. This method will give you some readiness of interpretation, and is somewhat comparable with the mental arrangement of the points of a mathematical problem before actually working it out.

Date all field-book entries, also traverses when plotted, and on the latter also give field-book date, with scale of the sketch. Such docketing will appeal to examiners desiring inspection of students' *actual* note-books. Examiners wish to see original first-hand work.

5. ADJUSTMENT OF ERROR IN TRAVERSING

Traversing cannot be used to make an accurate map of any large extent of country. There is always the possibility that distance lengths may be exaggerated, and that bearings may be taken inaccurately, perhaps through no fault of the observer. The compass may be defective or may be influenced by iron in rocks near points of observation. Theodolite traversing is rather more accurate, and is sometimes used in formal survey work in forested country such as Nigeria, where triangulation is hardly possible owing to the dense forests and the lack of suitable stations for observation. Traversing is also difficult because paths must be cut through the forest, and the hot, wet climate soon produces fresh vegetation on such clearings.

However, traversing has some uses, and when a traverse is made, it is desirable to check its accuracy. The most convenient ways of doing this are—

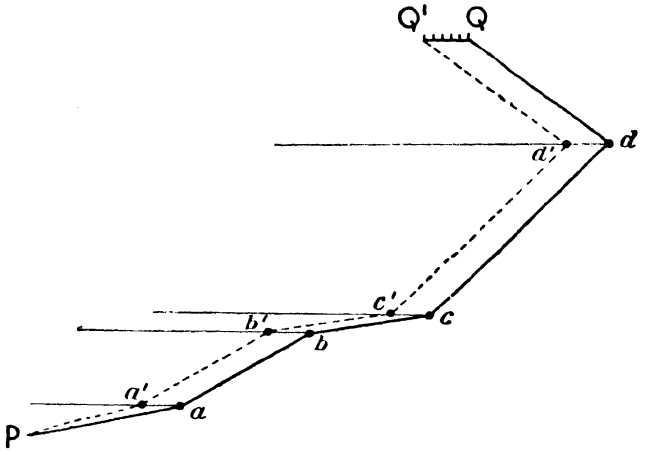


Fig. 102. ADJUSTMENT OF TRAVERSE ERROR.

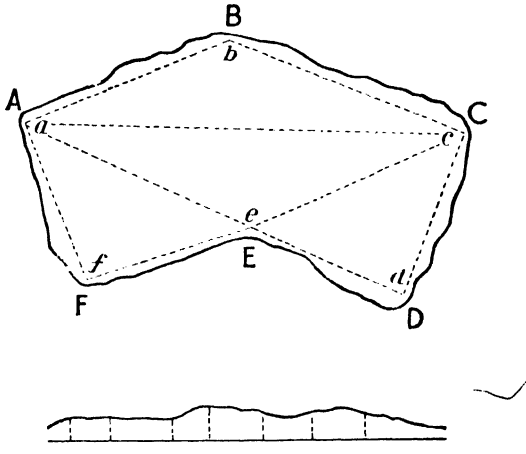
(1) From different halting-places in the line of traverse to take bearings on some prominent distant object, such as a church spire or tower or a mountain peak. In the Fens, Boston Church tower (Boston "Stump") is visible for many miles around, and bearings taken to it from "halts" should theoretically intersect when plotted. In practice they would not be likely to intersect, as few traverses are sufficiently accurate for such intersection to occur. Hence this method is not very satisfactory.

(2) By distribution of error. By referring to Fig. 102 the student can learn how errors in traversing are adjusted by this method.

P is the starting-point (a known fixed point), and Q the finishing-point of the traverse as plotted from the field-book entries, but Q′ is the actual known fixed

point where the traverse finished. Join Q to Q′ and through the plotted stations *d*, *c*, *b*, *a* draw lines *dd′*, *cc′*, *bb′*, *aa′* parallel to QQ′. Divide QQ′ into as many parts as there are legs to the traverse (here five). On *dd′* mark off similar parts, but one less than on QQ′; on *cc′* mark off part less than on *dd′*, and similarly for *bb′*, *aa′*. Join Q′, *d′*, *c′*, *b′*, *a′*, P by means of the dotted line, which is the adjusted traverse, with the error distributed proportionately.

If the traverse is closed, it is possible to adjust angular errors. It is a well-known geometrical truth that in a closed figure the sum of the interior angles plus four right angles is equal to twice as many right angles as there are sides. Hence from the sum of all the bearings we can take the sum of all the interior angles of the figure and distribute any difference equally among the bearings.



Chain Line, eg. ab, shewing offsets to field boundary

Fig. 103.

6. CHAIN TRAVERSE. USE OF THE CHAIN

In the survey of small properties, especially in detailed estate plans, a closed traverse is sometimes made by chain alone. What is termed a Gunter's chain is generally used. It is 22 yards long, and is subdivided into a hundred links. Every tenth link is marked by a brass tag, and the tags are marked to show 10, 20, 30 links, etc., from the zero end of the chain. In measurement of area, ten square chains are equivalent to an acre. Besides the chain a few simple articles are required, namely, some pointed pieces of iron called "arrows," generally ten, some ranging-rods tipped with iron to mark stations, and a graduated measuring rod or tape to ascertain the length of offsets.

The essence of this type of survey is that the position of each feature must be determined by measuring its perpendicular distance from a straight line, which

itself should be the side of a triangle. These perpendicular distances are called "offsets" and should be as short as possible. If they are short enough to be measured by a graduated offset rod, the result is more likely to be accurate than if the offsets are so long that a measuring tape is required.

In the survey of, say, a field, ABCDEF, the first thing is to make a rough sketch setting out suitable chain-lines, which indicate the sides of triangles, e.g. *ab*, *bc*, *cd*, etc., to be measured with the chain. (See Fig. 103.) These chain lines should be as near the field boundary as possible, so as to obtain short offsets. One or two diagonal lines, e.g. *ac*, *ae*, etc., will be desirable to complete the triangles.

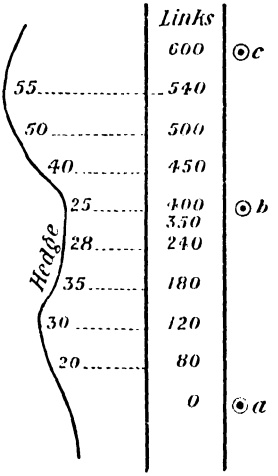


Fig. 104. Field-Book for Chain Measurement.

The chain lines are measured by a chainman (leader) and assistant. The assistant holds one end of the chain at a point *a* which is marked by a ranging-rod. The leader takes the other end of the chain and sets out along *ab* with ten arrows. He is guided by signals (left or right of his direction) from the assistant until he is in a line with the rod at *a*. Then he pulls the chain tight and puts an arrow in the ground to mark the end of the chain. The assistant now moves to the arrow, the leader carries his end of the chain forward and the process is repeated until *b* is reached. Measurements are duly entered in the field-book. Before the chain is moved, offsets are measured from *ab* to suitable points along the field boundary.

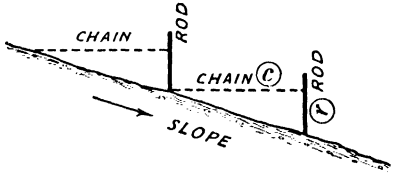


Fig. 105.

The field-book (see Fig. 104) is similar to that used for a compass traverse. Two parallel lines about an inch apart are ruled down the middle of the page for chain line entries, starting at the bottom of the page. A sketch of the boundaries is made on the right- or left-hand of the page according as they are left or right of the chain line, and measurements of offsets are entered between the centre columns and the boundary. The circles and dots indicate stations.

In sloping ground the horizontal distance is required. This is either read with a clinometer (see page 195) or measured by chaining-in steps. That is, one of the chainmen holds one end of the chain (*c*) against a ranging-rod (*r*) at a height which makes the chain seem horizontal when the other end is held on the ground. (See Fig. 105.)

7. THE PEDOGRAPH

The Pedograph (Fig. 106) is an automatic road tracer which reduces the method of traversing to a mechanical process and enables a person without previous training to produce a map to scale of any route walked over. The instrument consists of a recording device contained in a flat metal box about 12 inches square, and is carried by a sling in front of the operator. A compass with glass top and bottom, is let into the lid of the box, and contains a pair of parallel magnetic needles, pivoted in such a manner as to remain very steady notwithstanding the jolting motion of a walk.

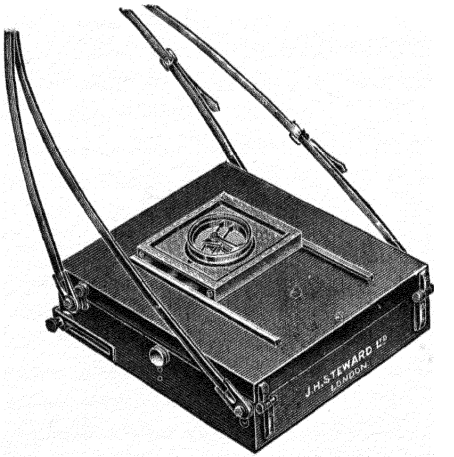


Fig. 106. PEDOGRAPH.

The route walked over is mapped on paper by a toothed wheel, which is caused to revolve by a pendulum oscillating vertically, in much the same way as the well-known pedometer hammer, but much more surely. The paper rests on a metal plate or plane-table and is gripped between the toothed wheel and a smooth wheel in the lid of the box. As the toothed wheel revolves it not only marks the paper, but also imparts a progressive action to it. In order to orient the paper correctly so that the distances recorded show the proper directions with all the angles and curves according to nature, the paper is ruled with parallel meridian lines, and these are visible below the compass needles.

As the operator walks along, he keeps the meridian lines on the paper parallel to the compass needles, by turning a knob which projects from the side of the box, and which slews the paper round. This adjustment is made with every change of direction shown by the compass needles, and the plan is thus correctly

oriented as it progresses. The smooth wheel above the toothed wheel is supplied with ink from a saturated pad, which renders visible the tracing made by the toothed wheel. The operator's position on map can be noted, and marked, and any necessary detail can be entered in a note-book under a similar reference mark. The recording device can be adjusted to plot maps to different scales ranging from a ratio of 1/10,000 to 1/100,000.

A route traced by the Pedograph compared with the same route on an Ordnance map, showed distances to be correct within about 3 per cent. and directions within about 2 degrees of accuracy. It is interesting to note that a large area of China has been successfully mapped with this instrument.

In hilly country all the curves of a route will be shown and reductions can be made by observations with a clinometer, but the Pedograph is not suitable for use in a mountainous country.[1]

Note. Professor F. Debenham's *Map Making* gives an interesting method (1) of plotting traverse results by co-ordinates and (2) of adjustment. See Figs. 28, 29 in that book, which also (Fig. 34) gives example of booking an Aneroid Traverse.

[1] For the above description of the Pedograph we are indebted to Messrs. J. H. Steward, Ltd.

CHAPTER XVII

CONTOURS AND CONTOURING

1. VERTICAL INTERVAL AND HORIZONTAL EQUIVALENT

In Chapter IV. it was pointed out that contours form the basis of most methods of showing relief. In connection with contouring, explanation of certain terms is necessary. The **Vertical Interval** (V.I.) is the difference between two successive contours. The **Horizontal Equivalent** (H.E.) is the horizontal distance between two successive contours. The V.I. on a map does not vary except when abnormally low or abnormally high ground renders variation desirable. In the Fens, if the normal V.I. of 100 ft. were retained, many small relief features would escape notice, so here contours of 50 ft. and 25 ft. are introduced. In the Scottish Highlands, on high slopes, contours with 100 ft. V.I. would coincide, so a V.I. larger than 100 ft. is used in such cases, though 100 ft. V.I. may suffice part of the way up the slope.

2. THE SCALE OF SLOPES

The **scale of slopes** must be considered in relation to the H.E., which varies according to the degree of slope.

The base of a right-angled triangle with an angle of 1° opposite the perpendicular is 57·3 times the length of the perpendicular. That is, for a slope of 1° the V.I. of 1 ft. corresponds to H.E. of 57·3 ft. The H.E. is always measured in yards, so 57·3 ft. = 19·1 yd., but to simplify calculation a round number, 20, is taken for this H.E. Taking D as the degree of slope, the above details can be expressed by formula giving approximate results for small angles, viz.

$$\text{H.E.} = \frac{20 \times \text{V.I.}}{\text{D}},$$

which is applicable to slopes up to 20°. Hence, if two of the terms H.E., V.I., and D. be known, the third can be found by a simple arithmetical calculation.

A scale of slopes can be constructed to show the H.E. for any degree of slope in connection with a particular V.I. Thus, if the V.I. be 50 ft.—

$$\text{H.E.} = \frac{20 \times 50}{1} = 1000 \text{ yd. for } 1° \text{ of slope}$$

$$= \frac{20 \times 50}{2} = 500 \text{ ,, ,, } 2° \text{ ,,}$$

$$= \frac{20 \times 50}{3} = 333 \text{ ,, ,, } 3° \text{ ,,}$$

$$= \frac{20 \times 50}{4} = 250 \text{ ,, ,, } 4° \text{ ,,}$$

$$= \frac{20 \times 50}{5} = 200 \text{ ,, ,, } 5° \text{ ,,}$$

and so on.

To make the scale, draw a line, and on it, bearing in mind the scale on which the map is drawn, mark off lengths of 1000, 500, 333 yd., etc., and label such divisions 1°, 2°, 3°, etc. Scales of slopes should be drawn for, and used with, specific maps. Except in very mountainous country, it will generally suffice to draw up the lengths of H.E. for every $\frac{1}{2}°$ from 1° to 15°. First, by means of the formula, after noting the V.I., reckon the necessary lengths for the H.E. corresponding with, say, every $\frac{1}{2}°$ of slope from 1° onwards. Before constructing the scale, tabulate such lengths and work out their relation to the scale of the map. Always head the scale with the V.I. for which it is to be used, and also note the scale of the map for which it is intended.

3. INSTRUMENTS USED IN THE DETERMINATION OF HEIGHTS

In making a topographical map, it is necessary to determine a framework of heights to serve as a basis for contouring. Some heights will be determined during triangulation and traversing when these processes are used, but others will be required. They may be determined by the use of certain instruments, namely—

(1) The **spirit level.**

(2) The **theodolite** (see page 160), which by giving vertical angles, supplies data for the computation of heights of lofty peaks or other inconvenient points.

(3) The **clinometer,** especially the Indian clinometer. It is useful for measurement over short distances.

(4) The **aneroid barometer.**

(5) The **hypsometer** or boiling point thermometer.

Authorities reckon that the relative accuracy of the various instruments is comparable with their order in the above list, but the Indian clinometer is many times more accurate than the ordinary instrument. Reasonably good, but not precise, levelling is held to give only an error of 0·3 ft. in about a 100 ml. ray. Careful topographical triangulation, using the theodolite, might result in an error of 20 ft. in 200 ml., there being much less error in the more elaborate methods of

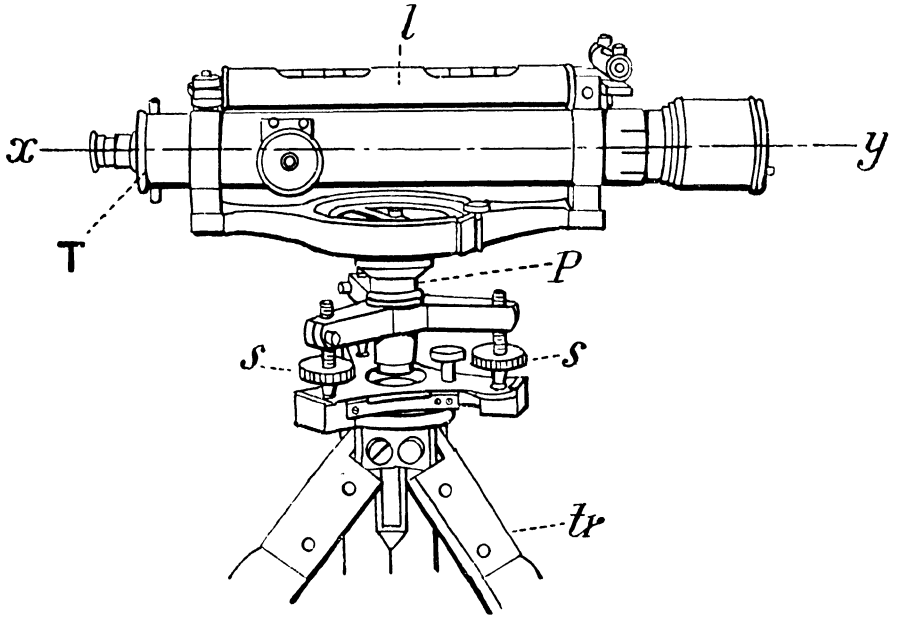


Fig. 107. Dumpy Level.

triangulation. A clinometer should not be used for a ray of more than 3 ml., and if carefully used will result in accuracy within a few feet. Under the most favourable conditions, an aneroid barometer used relatively to level or theodolite heights[1] should not give an error of more than 20 ft. If used independently, the error may be as much as 100 ft., and such an error is likely with the hypsometer, which would only be used during expeditions or in newly-developed country when no other method was available.

[1] See page 197.

THE SPIRIT LEVEL.—The level (see Fig. 107) is essentially a telescope, T, mounted on a tripod, *tr*, and set at right angles to a vertical axis. By means of a pivot, P, it can be revolved in a horizontal plane, and is so designed that objects seen on the cross-wires of the telescope are on the same level as such wires. There is a spirit level, *l*, fixed rigidly to the telescope and parallel to its line of sight, *xy*. The level, by means of levelling-screws, *s*, *s*, is mounted on a plate on top of a rigid tripod.

Sighting staves used with the level are from 10 to 15 ft. long; they are graduated in feet, with subdivisions of tenths and hundredths of a foot. Sometimes the levelling-staff has a small spirit level attached to ensure that the staff is held vertically.

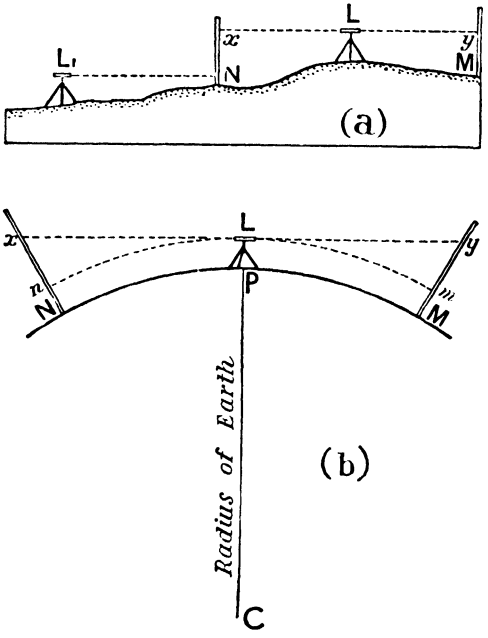


Fig. 108.

Using a Spirit Level. The level is set up at L (see Fig. 108*a*), with the tripod feet on a firm surface or well pushed into the ground, and by means of the levelling-screws it is adjusted so that the bubble of the spirit-level is in the centre of its run and is steady, no matter in what direction the telescope is pointed.

The staff is held vertically by an assistant, who rests its foot firmly on top of a mark, M, whose height above sea-level is known. The observer directs the telescope on the staff and notices where the cross-wires of the telescope cut the latter. If it is 4·34 ft. the line of sight of the telescope is 4·34 ft. above the level of the mark.

The staff is moved to N, as far behind the level as it was formerly in front of it. The telescope is turned so that it is directed on the staff in the latter's new

position. Another reading is taken, say 14·75 ft. The bottom of the staff is now 14·75 ft. below the line of sight of the telescope. That is, it is 14·75 — 4·34 = 10·41 ft. below the level of the mark on which the staff was first held. These readings are entered in the level-book, the first being known as a " back-reading," the second as a " forward-reading." The difference between them gives the difference in level between the stations where the staff was set up, and the height of the level itself above can be ignored. The level can then be moved to L_1, and the process repeated.

The reason why the level should be the same distance from the staff for back and forward readings is connected with the curvature of the earth. (See Fig. 108*b*.) The line of sight, *x*L*y*, of the telescope is perpendicular to the earth's radius, PC, at the point, P, where the level is set up. In the line of sight L is nearer the earth's surface than either N or M; it is nearer by *xn* or *ym*. But if N and M are equal distances from P, the excess *xn* and *ym* will be equal, and thus there will be compensation of any error.

The distance from the level to the staff should not be so great that the curvature of the earth will be marked. If possible, the distance should be under rather than over 200 yd. The earth's curvature brings in an error of about 1 in. in 220 yd. Lines of level need not necessarily begin at a point the level of which is known. They should either begin or end at a point of known level, or they should end at the point where they began. In the latter case the line of level would be closed, but some point in the line of level should be known so that errors in levelling can be detected.

The Theodolite.—For an explanation of the theodolite see Chapter XIV. The vertical circle is used for measuring vertical angles, and the theodolite is the most accurate instrument for determining heights.

The Clinometer.—The clinometer is an instrument designed to measure vertical angles. There are many types of clinometer, but the principle of each is essentially the same.

The slope of an object is represented by the number of degrees the object is out of the horizontal. That is, it is represented by the angle contained by (1) a straight line drawn from the observer's eye; and (2) a horizontal line passing through the observer's eye. Such angle is measured by the clinometer. It is easy to imagine a straight line from the observer's eye to the object, but much less easy to obtain a really horizontal line.

A horizontal line can be obtained by a spirit level, and some clinometers have such a level attached. A horizontal line can also be obtained by first getting a vertical line and taking a line at right angles to it as horizontal. A vertical line can be obtained by means of a plumb-line, which is included with some types of clinometer.

The Abney Level. A well-known type of clinometer is the Abney level. (See Fig. 109.) This is essentially a telescope, T, to which is firmly fixed a protractor, P. This is read by a vernier, *v*, carried on an arm, *a*, pivoted at

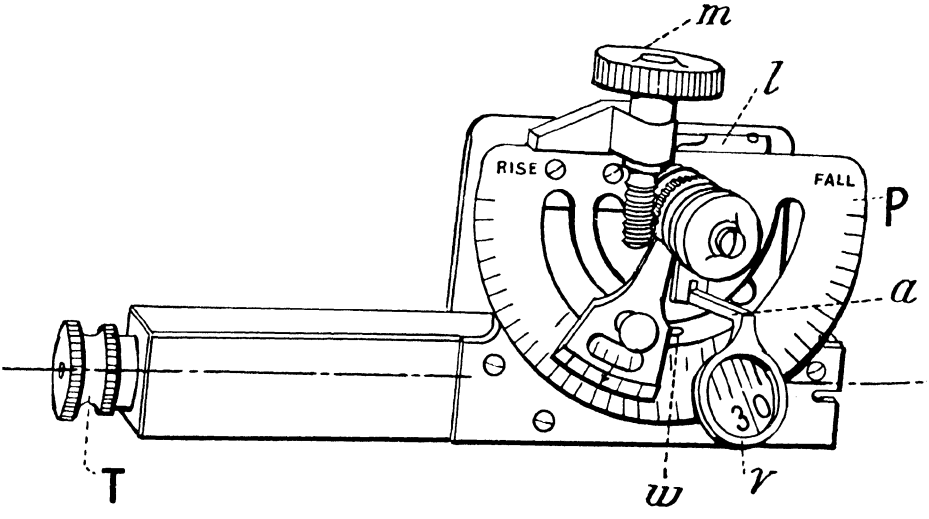


Fig. 109. The Abney-Steward Reflecting Level and Clinometer.

the centre of the protractor. A spirit level, *l*, is fixed rigidly so that it is at right angles to the arm, which carries a milled knob, enabling the level to be moved. The spirit level is parallel to the line of sight. Under the centre of the level there is a window, *w*, cut in the telescope, and inside the telescope is a small plane mirror at an angle of 45° to the line of sight, *xy*, of the telescope. When the observer uses the instrument to find an angle of depression or elevation, he looks through the telescope at the object, which should appear on the cross-wire of the diaphragm. He then turns the knob carrying the spirit level until he sees the

bubble of the level reflected in the mirror on the telescope cross-wire. The spirit level is horizontal and the required angle is read.

If the object is shown on a map, the observer's position can be found by resection (p. 175), and the distance calculated by means of the map scale.

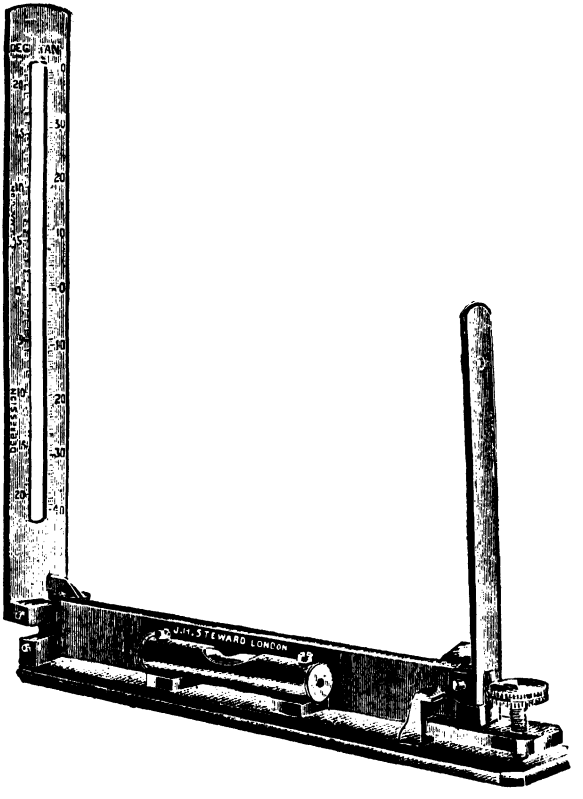


Fig. 110. INDIAN CLINOMETER.

The Indian Clinometer. The most accurate contouring can be done with the Indian clinometer. This is a brass base plate with a bubble and levelling-screw, and two folding leaves can be made to stand up, one at each end of the base. (See Figs. 110 and 111.) One leaf, I, has a small sight. The other leaf, II, has a vertical slit graduated along one edge in a scale of degrees and along the other edge in a scale of what in trigonometry are called tangents of degrees. The zero of each scale is at Z, on a level with the sight-hole, S, of the leaf I.

The graduation at x shows the value of the ratio $\frac{Zx}{SZ'}$, which remains constant whatever the distance from S to the object sighted.

If we look at the distant object, x' (Fig. 112), and read, say 0·2 at x, on the tangent scale, we know that the fall from the level of the clinometer at S is 0·2 of the horizontal distance Sz'. The horizontal distance, by means of the scale, can be measured from the plan or map. It is desirable that a scale be drawn carefully for every plan or map made. (See Chapter II., Scales.)

Similarly, in Fig. 113 a reading of 0·2 at x would mean that the rise from the level at S is 0·2 of the horizontal distance Sz^2.

It is important that the height of the clinometer above the station of observation should be subtracted from a fall or added to a rise.

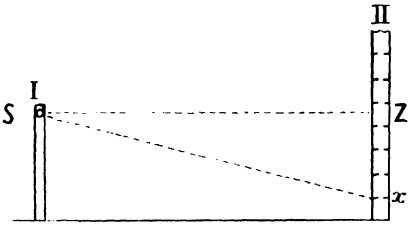


Fig. 111. Indian Clinometer.

The Aneroid Barometer.—The aneroid barometer (Figs. 114 and 115) is graduated to show a scale of feet to considerable heights, such as 15,000 or 20,000. The principle of the instrument for reading heights is that the reading of the barometer varies with altitude, because the density of the air so varies and consequently pressure on the "drum" varies. It is necessary to observe corrections for temperature of the barometer and of the surrounding air. Such corrections are given in prepared tables. The reliability of the barometer varies with different weather conditions. A rough check is possible by using two instruments and taking a mean of their readings.

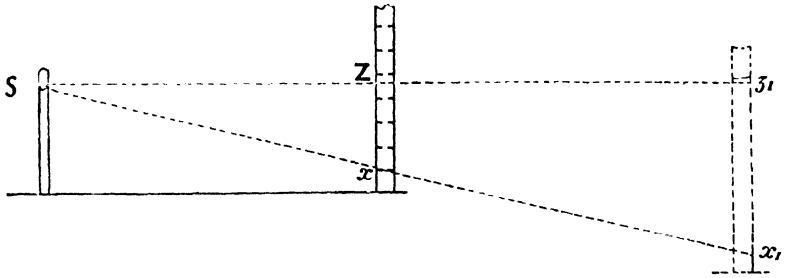


Fig. 112. Indian Clinometer.

In using the barometer to fix the approximate position of contours, the observer should work between points of known height. If the student knows the height of stations in a valley, say 568 ft., and on a hill-top, say 1,020 ft., the barometer would be set to the known height at the valley station. The observer would then move along some convenient salient, halting when the barometer showed the required contour readings (say with V.I. 100 ft.). Such points where

the 600, 700, 800 ft. contours are shown should be fixed by means of a plane-table. If the barometer reading differs from the known height of the hill station, there should be proportionate correction of all the contours.

Barometer heights are useful where it is not possible to fix a trigonometrical station, as in forests, deep valleys observed from a height, etc.

THE HYPSOMETER.—This is à thermometer graduated from 180° F. to 212° F., which fits into a tube itself fitting into a small tank containing water and heated by a spirit lamp. The principle underlying its use recognises that the temperature at which water boils is lowered as the altitude increases. By means of tables it

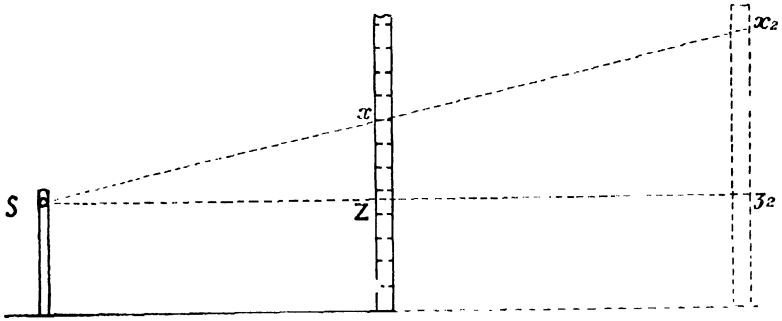


Fig. 113. INDIAN CLINOMETER.

is possible to determine heights approximately after noting the reading on the hypsometer when the water boils and the mercury is steady.

4. CONTOURING

It is assumed that the general plan, *without the hills*, of an area, has been made by triangulation (see page 158) or traverse (page 180), and that it is desired to contour the ground systematically.

It is best to begin somewhere near the highest part. First examine the general character of the ground carefully, noting the principal salients[1] and re-entrants which mark the most noticeable spurs and stream courses: start with a hill. (See page 193 on levelling.)

[1] A **spur** (salient) is a prominent feature projecting from high ground into lower ground. A **re-entrant** is a depression in the side of a hill.

The first contour should be made at a distance below the summit somewhat less than the V.I. intended. A line should be levelled round the hill. P (see Fig. 116) represents the position of the observer from which this line is levelled. A piece of white paper is fastened to a staff at a height above ground-level corresponding with that of the observer's eye at the clinometer. Then, with the clinometer at zero, a sight is taken on the paper on the stick at *a*. The stick is moved to other suitable positions, *b*, *c*, etc., which

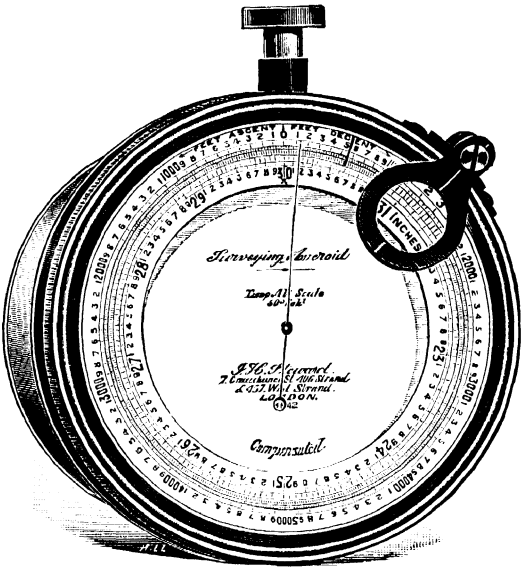


Fig. 114. Hypsometric Aneroid.

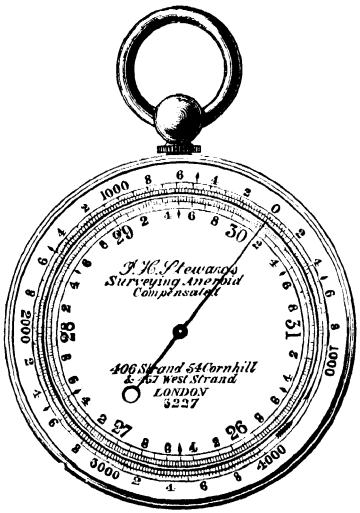


Fig. 115. Open Range Aneroid.

are similarly fixed on the ground and then on the sketch by resection, traverse, etc. The positions *a*, *b*, *c*, etc., must be the same height relative to P. These positions should be a guide to spurs or re-entrants, and by joining them the first contour is drawn. At each of the positions *a*, *b*, *c*, the map is set (see page 14), and rays (shown by dotted lines in the diagram) are drawn along the various spurs and re-entrants. As far as possible they should be drawn along the ridge-line of a spur, or along the thalweg (= valley-line) of a re-entrant, and the slope is measured in their direction, but if there is a change in direction of the spur or re-entrant, the sketch must be set afresh and another ray drawn.

If preferred, bearings along the spurs can be taken with compass and plotted with protractor (see page 183) instead of obtaining rays by setting the sketch.

Now measure the slope, starting at *a*. The slope measures, say, $4\frac{1}{2}°$ without any change of slope along the ray. If the V.I. is to be 10 ft., the H.E. will be 44 yd., and, bearing in mind the scale, distances corresponding to 44 yd. are marked off along the ray on the sketch. Similarly, there is no change of slope along the ray from *b*, and the same procedure is followed. The slope here is 4°, and distances corresponding to 50 yd. are marked along the ray on the sketch.

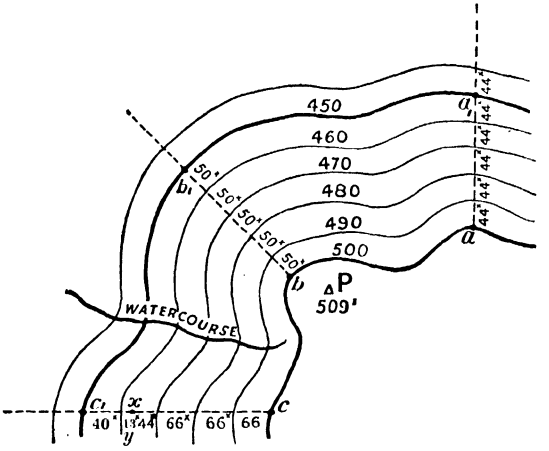


Fig. 116. Levelling.

Along the ray from *c*, the slope measures 3° for 242 yd.,[1] but then, at a point marked *x* on Fig. 116 it changes to 5°. From *c* to *x* mark off H.E. intervals equivalent to 66 yd. The last contour before the change of slope will be $66 \times 3 = 198$ yd. from C, and the change of slope is $242 - 198 = 44$ yd. beyond this contour. This is $\frac{44}{66}$ of the V.I., *i.e.* $6\frac{2}{3}$ ft. with a slope of 3° and the remaining $3\frac{1}{3}$ ft. with a slope of 5°. For V.I. 10 ft., H.E. for slope of 3° is 66 yd.; therefore for $6\frac{2}{3}$ ft. of the V.I. it will be 44 yd. First contour after change of slope $= \frac{3\frac{1}{3} \times 20}{5} = 13$ yd. from point of change. Indicate this contour by *y*, and from *y* mark intervals to correspond to 40 yd. H.E. for 5° slope.

The process is continued along the other rays. When the crestline is near the head of a watercourse, direction of latter should be sketched as a guide.

In measuring the slope, very small undulations can be neglected, but if at the change of slope there is anything, as a tree, about 5 ft. high, the angle of

[1] *Note.*—*x* is fixed on sketch and scale gives 242 yd. from *c* to *x*.

depression to the top of this object should be taken by the observer standing. Where no such object intervenes, the clinometer should be read close to the ground or staves.

If the point P coincides with the spot height of an official topographical map, the contours can be numbered relative to it. If no such height is available, the contours are merely relative to one another, and the lowest can be reckoned as zero.

When points for the contour lines have been fixed, it is well to check the work and by deliberate observation to fix the position of at least one contour, e.g. *a'b'c'*, other than the initial contour *abc*. This can be done by levelling as in the case of the initial contour.

To Contour a Sand Dune.

First draw a rough plan of the dune, not attempting anything but a rough approximation to scale, and indicate lines along which sights are to be taken. (See Fig. 117.)

Certain preliminary considerations are necessary. The horizontal scale must be selected, say 1 in. = 25 yd. or 50 yd. according to the size of the dune; the Vertical Interval must also be selected, say 10 ft., and a scale of slopes must be constructed as explained in Section 2, page 190.

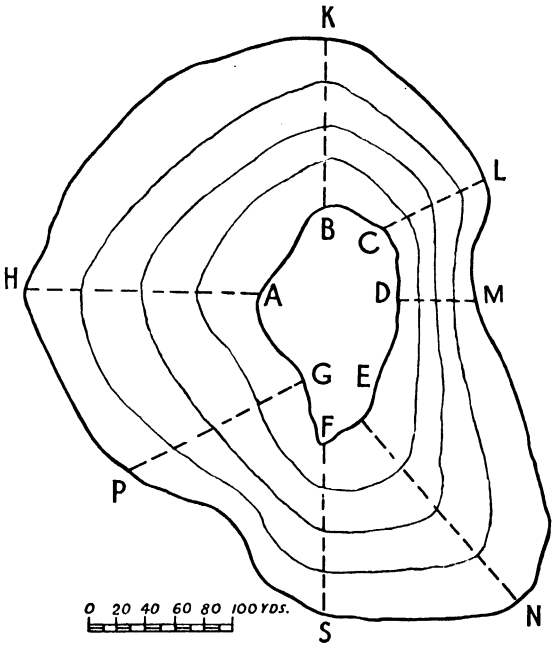


Fig. 117. Contours of Sand Dune.

Begin by levelling a line all round the dune at a smaller distance from the crest than the Vertical Interval; a suitable distance would be 5 or 6 ft. Points from which sights are taken must be on this line, *e.g.* A, B, C, D, E, F, G.

Next decide the lower points to be sighted from these stations, *e.g.* H, K, L, M, N, S, P. These are to be the same height above sea-level.

Observation by clinometer shows AH to be 5°, BK 8°, CL 16°, DM 20°, EN 5°, FS 8°, GP 7°.

Use is made of the table of slopes.

The H.E. for AH is $\frac{20 \times 10}{5} = 40$ yd. (also for EN)

BK $\frac{20 \times 10}{8} = 25$,, (also for FS)

CL $\frac{20 \times 10}{16} = 12\frac{1}{2}$,,

DM $\frac{20 \times 10}{20} = 10$,,

GP $\frac{20 \times 10}{7} = 28\frac{4}{7}$,,

Choosing a suitable scale, mark off from the rays AH, EN distances corresponding to 40 yd., on BK, FS, corresponding to 25 yd., on CL, DM, GP, corresponding to $12\frac{1}{2}$, 10, $28\frac{4}{7}$ yd., respectively. Then join the points of intersection, sketching in to show the contours.

The precautions necessary in taking observations are (1) that the line of sight must be parallel to the ground, and thus the object sighted should be the same height above the ground as that of the clinometer; (2) that a check should be taken by reading from the first object sighted to the observer's original position, and the angles read should be equal, but in an opposite sense; (3) that a fresh reading should be taken from the original position if the mean of the readings taken under (2) differs much from the original reading.

CHAPTER XVIII

HINTS FOR THE INTERPRETATION OF GEOLOGICAL MAPS

1. THE NATURE OF GEOLOGICAL MAPS

Geological maps are very useful to the geographer in helping him to understand the character of physical features and soils, the distribution of minerals, and the problem of water supply. He does not need to study them with that intensity and attention to technical detail necessary in the case of the trained geologist or the mining engineer, but he must grasp certain broad principles.

Geological maps contain information with respect to the nature, age, and relation of rocks which constitute the upper part of the earth's crust. They also indicate the way in which the various beds of rock are inclined. It is possible to draw sections illustrating the relative positions the rocks would occupy in a solid model. Such sections are a great help when we examine the physical geography of a region of contrasted relief where hills and valleys alternate. Both Ordnance Survey and Geological maps can be read without drawing sections, but practice in drawing such sections leads to facility in grasping the essential details and in interpreting the map.

The geological map, in addition to details concerning the rocks, contains much of the information given by the ordinary topographical map, such as streams, routes, and settlements. One-inch Geological Survey maps show contour lines, bench marks, and trigonometrical stations, but it is an advantage to use an Ordnance Survey map for the relief, because the data can be more readily seen.

The geological map, by means of different colours or stippling, shows the character and extent of the rocks which constitute the earth's surface. Symbols are used to denote the position and extent of mineral veins and fractures (known as " faults ") which have affected the general relationship of rocks in some

districts. These can be seen in the keys printed on the margin of all geological maps. The following symbols may be specially noted:—

↘ 10° Denotes a dip (in quarries, railway cuttings, etc.) of 10° to S.E. at the point where the arrow appears on the map.

8° ↖ A dip of 8° to N.W.

↘ Indicates direction, but not amount of dip. (Usually dip is small in these cases.)

\+ Indicates horizontal strata.

⟋ Indicates vertical strata: longer line gives ⟍ strike direction.

⟍ Undulating beds.

+ Anticlinal axis (top of an arch of upfold).

✳ Synclinal axis (*i.e.* bottom of a downfold).

For England and Wales there are two kinds of geological maps for certain districts, namely the **solid** and **drift** editions. The solid map shows everything except glacial deposits, and includes peat, alluvium, river terraces, older river gravel, blown sand. The drift edition shows all recent deposits as well as (1) glacial drift; (2) older formations where these are not covered by any of the newer deposits. Drift maps are published for those regions, especially Eastern and Northern England, which were formerly overlaid by the ice-sheets of the Ice Age. When possible, both the drift and solid geological map of the region should be used. The former is invaluable in explaining the soil variations; the latter is useful for study of land-forms and water-supply.

2. THE CLASSIFICATION OF ROCKS ACCORDING TO ORIGIN

Rocks of the earth's crust, according to their origin, are divided into three main classes: (1) igneous, (2) sedimentary, (3) metamorphic.

Igneous Rocks.—These are due to the cooling and solidifying of molten matter. They comprise lava ejected from volcanoes and from fissures (or cracks in the earth's surface), as well as molten matter which has crystallised below the surface and was exposed when erosion removed overlying rock. Granite and basalt are well-known igneous rocks.

Sedimentary Rocks.—Sedimentary rocks have accumulated as sediment at the bottom of seas, lakes, and river mouths, and were formed in relatively horizontal layers, though since formation they have often been changed by certain forces from their original horizontal position. Some sedimentary rocks, such as sand, are due to accumulation of fine-grained material, largely quartz, which has been worn down by wind from débris eroded from other rocks.

Well-known sedimentary rocks are sandstone, grits, clay, shale, limestone. **Sandstone** is formed when sand is made coherent by some cementing material such as calcium carbonate or oxide of iron. **Grits** comprise sandstones in which the original grains of sand are mainly angular. **Clay** is a fine-grained deposit, largely a hydrated silicate of aluminium, which is plastic because of the moisture which it contains. **Shale** is a clay or silt which has been hardened and laminated, that is, arranged in a series of layers. **Limestone** consists mainly of calcium carbonate derived from shells and skeletons of shell-fish, corals, and other creatures in the sea in which it was formed. Limestone is either hard or soft, in which latter form it is known as **chalk.** Not all limestones or other sedimentaries have originated "first-hand," some are due to wearing away of former sedimentary, igneous, and metamorphic rocks, and to redeposition of the débris.

METAMORPHIC ROCKS.—These have been formed by some great alteration of some other rock, which, before change, may have been of igneous or sedimentary origin. The alteration has been due to great pressure, heat, or a combination of heat and pressure. Metamorphic rocks are generally very highly crystalline, and those due to pressure usually much crumpled and contorted. Gneiss, crystalline schist, marble, and slate, are metamorphic rocks.

3. THE CLASSIFICATION OF ROCKS ACCORDING TO AGE

Rocks are also classified according to their age, and a grasp of this method is necessary to understand geological maps. The rocks are divided into groups or formations according to their geological age. Some of the principal formations noted on British maps are here given, arranged in the order normally followed in keys to the geological map, namely, the newest rock at the top and the oldest at the bottom. The lowest formation takes number 1 and letter *a*, and other numbers work upwards with letters according to alphabetical order.

26 Recent and Pleistocene, comprising alluvial drift, such as silt and gravel; peat; glacial drift, such as boulder clay, sand and gravel.
25 Pliocene: a group of shelly sands and gravels, with occasional seams of clay.
24 Oligocene: shelly clays, sands, and limestones.
23 Upper Eocene: sands and clays.
22 Lower Eocene: clay (London and other clays), and sands.
21 Chalk.
20 Upper Greensand and Gault Clay.
19 Lower Greensand.

18 Wealden: Weald Clay, Hastings Beds (sands, sandstones, and clays).
(Nos. 18-21 are known as Cretaceous rocks.)
17 Purbeck Beds: clays and limestones.
16 Upper Oolite: Portland Beds (limestones and sands), Kimeridge Clay.
15 Middle Oolite: Corallian (limestones and sands), Oxford Clay, Kellaways Beds.
14 Lower Oolite: Inferior Oolite (sands and limestone), Great Oolite (clays and limestone), Cornbrash (limestone).
13 Lias: upper (shales), middle (ironstone, limestone, sands, and clays), lower (clays and limestone). (Nos. 13 to 17 are known as Jurassic rocks.)
12. Upper Trias (Rhaetic, Keuper): marls, shales, sandstones, and rock salt.
11. Lower Trias (Bunter): sandstones, sands, and pebble-beds.
10. Permian: (*a*) magnesian limestone, (*b*) sandstone, conglomerate, marl.
9. Coal Measures: shales, sandstones, clays, fire-clays, iron-ores.
8. Millstone Grit: grits, sandstones, shales.
7. Yoredale Series: shales and limestone.
6. Carboniferous Limestone.
5. Devonian: shales, grits, and Old Red Sandstone.
4. Silurian: shales and grits.
3. Ordovician: limestone, slates, and grits.
2. Cambrian: slates and grits.
1. Pre-Cambrian or Archaean: schists, slates, grits, Torridonian Sandstones. Such rocks are largely metamorphic.

Nos. 2–26 above are classed as sedimentary rocks, and contain fossils. They are broadly arranged in groups according to age, namely **Primary,** the oldest, Nos. 2–9; **Secondary,** Nos. 10–21; **Tertiary,** Nos. 22–25; **Quaternary,** No. 26.

Some pre-Cambrian rocks, *e.g.* Torridonian Sandstone, are also sedimentary in origin.

Igneous rocks are of all ages, some of the best-known being granite, basalt, and serpentine rocks.

On geological maps rocks are distinguished by various colours, and sometimes by the addition of a distinguishing letter and number, for example, *Pleistocene* rocks are shown by buff and the letter *l*; *Cretaceous* by various shades of green and the letter *h*: Wealden Beds by h^1, Lower Greensand by h^2, Gault by h^3, etc.; *Jurassic* by browns and yellows and the letter *g*; *Triassic* by pinks and the letter *f*; *Cambrian* by pale grey and the letter *a*.

Igneous rocks are always put at the bottom of an index list, whatever their age. Basalt is shown by the letter B, granite by G.

There are special colours, with symbols, to indicate peat, alluvium, river terraces (often gravel), boulder clay, glacial sands, and gravels.

4. THE INTERPRETATION OF GEOLOGICAL MAPS

In interpreting a geological map, the first thing to do is to examine the map generally in order to see what formations are depicted on it. Then look for drift, which may occur in fairly continuous strips and patches, or in very small patches. It is well to realise that all drift is but a thin layer resting on the solid beds, and as a rule detailed consideration of drift should be left until the solid rock has been examined. At first it is well to picture the map as though the drift were not there. Sometimes the junctions of the solid rocks below the drift are shown by dotted lines, as in Fig. 118, and Fig. 119 shows how the solid beds should be pictured apart from the drift.

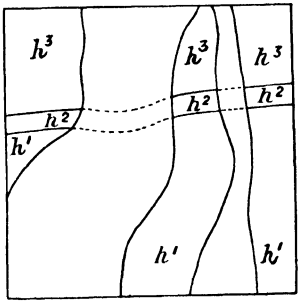


Fig. 118.

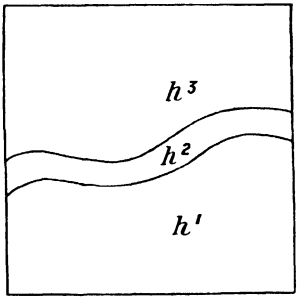


Fig. 119.

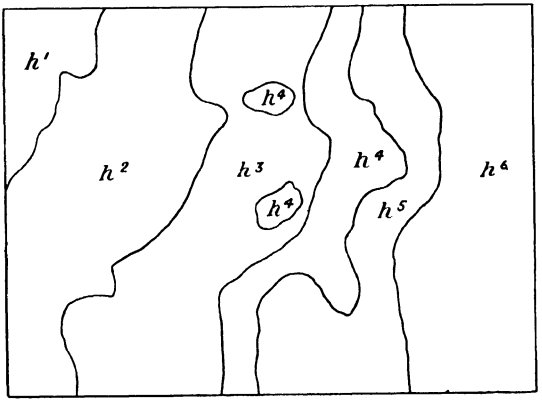


Fig. 120.

Beds of sedimentary rocks were laid down as relatively horizontal sheets (or **strata** as they are sometimes termed) of fairly uniform thickness. Many strata have later been tilted and folded, though the tilt or fold was often very slight. Despite such folding or tilting the strata lie one on the other very like the parts in the volume of a periodical. Thus, if any particular bed **outcrops** (or appears at the surface) it is easy to reach an older bed below it.

After general examination of the map and picturing it apart from the drift, you should ascertain where the newest or youngest beds lie. In Fig. 120 it is

evident that there is considerable outcrop of h^6 beds towards the east. Unless there is distinctly high land in the east, a fact determinable from the relief map, it is clear that the series of deposits h^1 to h^6 must have a "**dip**" (or downward trend) towards the east (Fig. 121). The beds h^1, h^2, h^3 must drop some considerable depth below the surface to allow room for the other members of the series. This method is reliable in picturing the dip of beds in relatively flat or undulating country. The inclination or dip of the bed must not be confused with *slope* of the ground.

If the ground rose towards the east, the strata might lie relatively horizontally (Fig. 122) or might dip slightly towards the west (Fig. 123). When lines

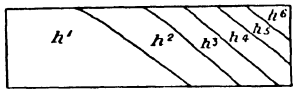


Fig. 121.

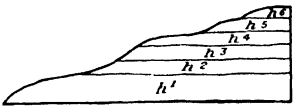


Fig. 122.

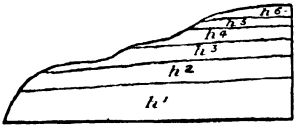


Fig. 123.

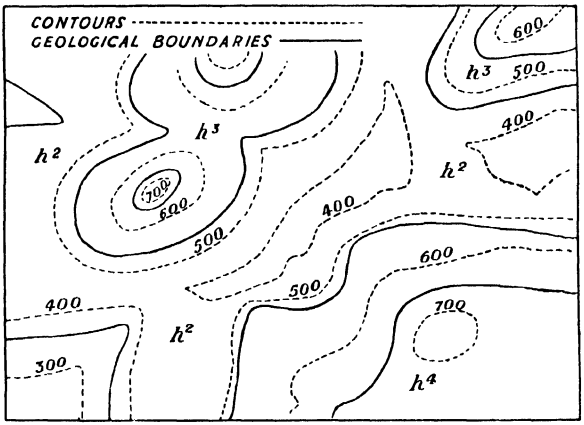


Fig. 124. (Fig. 125 is section from S.E. to N.W. of Fig. 124.)

indicating geological junctions run roughly parallel to the contours (Fig. 124) the strata are generally horizontal. When the beds are horizontal, outcrops of the newer rocks are found wherever there are hills, and not merely in one particular part of the map as might be the case when there is a tilt. The patches of newest rock forming the hill-tops are termed **outliers.** In such a case it is easy to visualise the profile of the country, to see it as it were, like a block model which has been cut downwards to expose a "section" showing the various strata. (Fig. 125.) Outliers could occur in other ways, not necessarily on hill tops.

Beds, however, are rarely quite horizontal. Wherever there is a slight dip the geological junction lines cut across the contours. In Fig. 126 at A the junction

is 500 ft. above sea-level; at B it is only 400. Then there is apparently a dip of 100 ft. in a south-easterly direction along the line AB.

If the junctions are independent of the contours and the outcrops are narrow (Fig. 127), the beds are nearly or quite vertical (Fig. 128). This does not often occur. Beds dipping gently are more usual. Diagrams 127 to 134 illustrate dip.

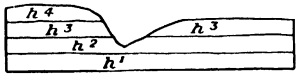


Fig. 125.

Dip is expressed in degrees from the horizontal. Where it can be observed in quarries, cuttings, or other exposures, it is shown on the map by dip arrows. The dip is denoted where the *point* of the arrow is on the map. Often a dip arrow without number is given: in such cases direction but not amount is indicated.

Reference is here made to the true or maximum dip, and not to what is known as apparent dip. True dip is in a direction at right angles to the strike; dip in any other direction is less and is termed apparent dip. The strike of a

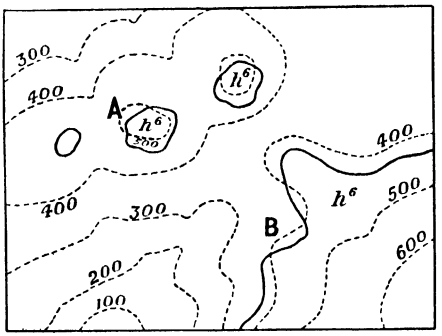


Fig. 126.

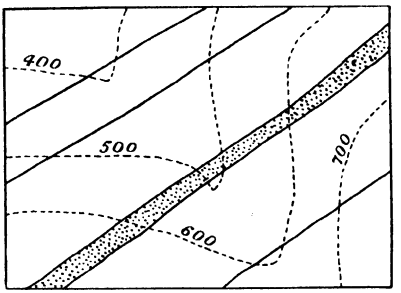


Fig. 127.

bed is its intersection with a level plane. Such terms are illustrated in books mentioned on page 244.

Note that Figs. 127, 129, 131, 133 are maps, and Figs. 128, 130, 132, 134 approximate geological sections, Fig. 128 being made from Fig. 127, etc.

Where strata have been folded in the form of an **upfold** or arch, sometimes called an **anticline,** a strip of old strata is bounded on both sides by newer formations (Figs. 131, 132). Where folding has been in the form of a **downfold** or **syncline,** outcrops of older rocks are on both sides of a strip of newer rocks

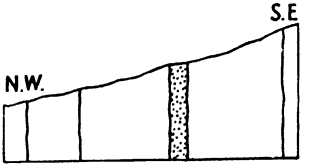


Fig. 128.

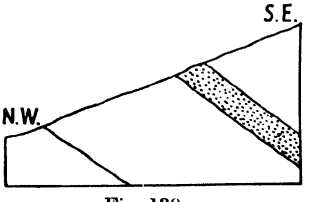


Fig. 130.

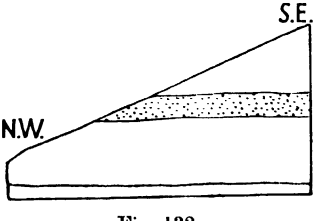


Fig. 132.

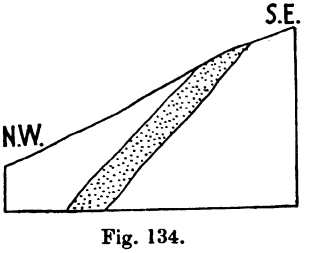


Fig. 134.

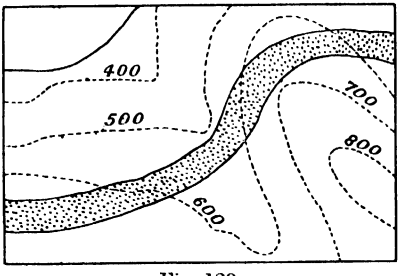


Fig. 129.

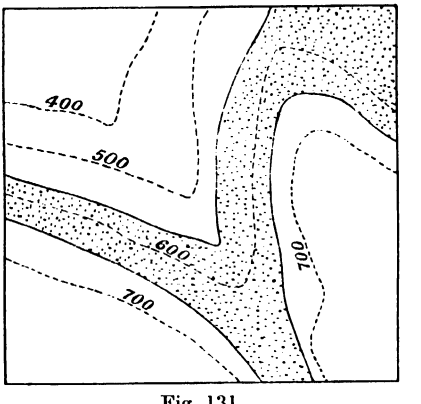


Fig. 131.

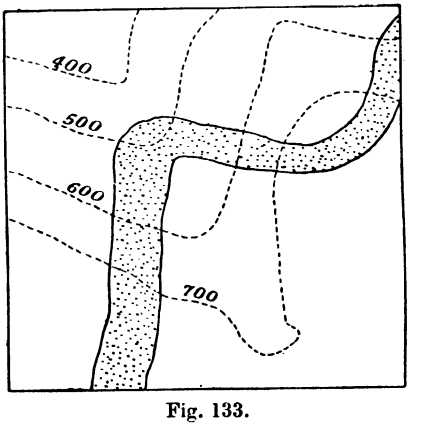


Fig. 133.

(Figs. 137, 138). Fig. 138 might be the section of a " basin " as well as of a downfold. The axis of both an upfold or downfold may be horizontal, though it may pitch or slope one or two ways.

The above diagrams are generalised sections drawn approximately, but sections should be drawn carefully from the maps with attention to available data.

In the diagram (Fig. 139) θ represents the angle of dip, x the width of outcrop,

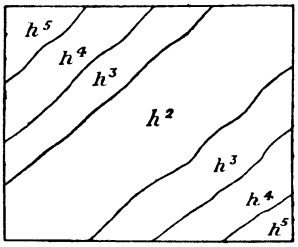


Fig. 135.

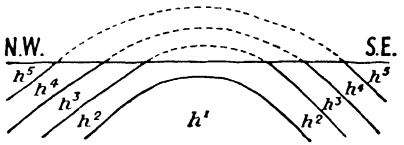


Fig. 136.

y the thickness of the bed, and z its depth. If the width of outcrop (measurable from the map) and the angle of dip are known, the other values may be calculated thus:—

$$y = x \sin \theta; \quad z = x \tan \theta.$$

Sin θ and tan θ can be found from a table of natural sines and natural tangents. And $x \sin \theta$ means x multiplied by value of the sine of the angle θ.

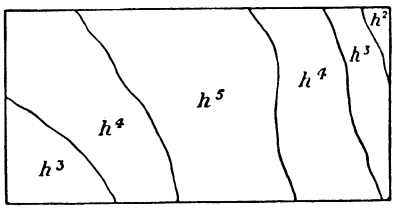


Fig. 137.

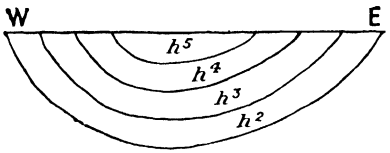


Fig. 138.

The thickness or depth of a bed can be obtained graphically. Thus (Fig. 139) draw angle NMP (*i.e.* θ) equal to the known angle of dip and mark off from M along MN the width of outcrop MN ($=x$). To obtain the vertical depth of the bed, draw from N a line NP at right angles to MN, cutting MP at P. This line NP ($= z$) is the required vertical depth. The true thickness is given by dropping from N a line NQ ($= y$) perpendicular to MP. This line NQ is the true thickness.

Dip, width, and thickness being known, we use such data in an ordinary topographical section drawn to scale from a contoured map. Note the section (Fig. 141) drawn from the contoured map (Fig. 140), the geological data being duly filled in from the geological map (Fig. 142).

A solid geological map shows the rocks *in situ*, that is, in their own positions where formed. A solid geological map of Lincolnshire will show the chalk of the Wolds, the limestone of the Lincoln Heights, the clay of the vale west of the Wolds. These rocks in many places are mantled with boulder clay, glacial sand, and gravel associated with the ice-sheet which once covered this country. These glacial deposits, as well as the alluvial deposits due to streams, are shown on the drift map. The best way to combine a study of contours and geological data is to make tracings of (1) the contours, and (2) the streams of the relief map, (3) the solid geological map, (4) the drift geological map. These can be placed one on another. The drift map explains soils, boulder clay giving heavy soil difficult to work, and sand giving poor light soil; and it also accounts for the character of the clay in the Lincolnshire and Norfolk marshes, and the character of the boulder clay cliffs of Holderness or the "island" sites of gravel in the Fens where towns were originally built. There are no glacial deposits in Britain south of the Thames, and thus drift maps are not necessary here.

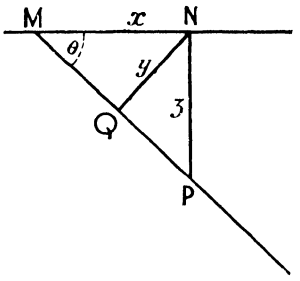


Fig. 139.

5. GENERAL GEOGRAPHICAL FEATURES OF CERTAIN ROCKS

The **London Clay** of the London Basin forms undulating country, well timbered and mostly grassland, but the soil is stiff. The **Chalk** of the scarplands, because of its uniform response to erosion, forms smooth, rolling, down country, like the North and South Downs, the Wolds, and Chilterns. The **Lower Greensand** forms gorse-covered, heathery commons and pine woods, like Hind-head and Leith Hill. **Weald Clay** and the **Sand** and **Sandstones** of the **Hastings' Beds** give picturesque, wooded, and cultivated areas in the **Weald** region. The **Kimeridge Clay** forms a series of vales, affording rich pasture land suited for dairying in Dorsetshire and Wiltshire. The **Oxford Clay** vales in Wiltshire, Bedford, Lincoln, and Yorkshire have similar characteristics. The **Limestone**, as a rule, forms hills, like the

Cotswolds and the Cleveland Hills. The **Permian Sandstones** give picturesque hilly country, with deep red lanes and fertile soil in Devon and Somerset. The **Millstone Grit** forms high moorland regions, with picturesque crags, as in the Pennine district. The **Carboniferous Limestone** gives a " karst " type of country, with underground drainage, etc., in the Mendip region of Somersetshire, or the Pennines in Derbyshire, where it tends to be picturesque moorland. The hard **Devonian** rocks, **Slates,** and **Sandstones** form high moorlands, mainly broad, rounded hills with steep slopes. The **Silurian sandstones, shales, grits** give highland like the Lake District and Southern Uplands of Scotland. The

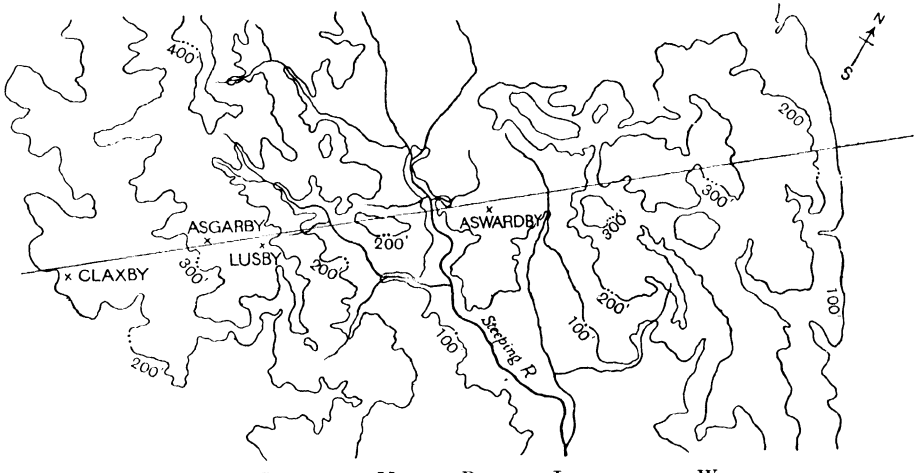


Fig. 140. Contoured Map of Part of Lincolnshire Wolds.
Showing direction of Geological section given as Fig. 141. Scale of Figs. 140, 142, and horizontal scale of Fig. 141 is identical.

Ordovician rocks give the mountainous district round Snowdon and the rougher mountains of the Lake District. Mountains and moorlands are formed by the **Cambrian** rocks, as in Wales, the Malverns. **Granite** and other crystalline rocks are associated with rugged mountainous or upland country, as in the Scottish Highlands and the higher land of Devon-Cornwall.

The foregoing hints are intended to provide for the simpler general cases of geological data, and are merely introductory to more technical treatment in specialised textbooks. Hence, such important subjects as faulting, the various kinds of folds, overthrusts, etc., are not treated here.

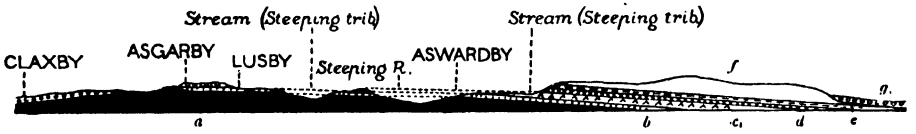


Fig. 141. Geological Section across part of Lincolnshire Wolds.

See Figs. 140 and 142. Vertical Scale exaggerated 6½ times. This section is adapted from the relevant Geological Survey Memoir by permission of the Director of the Geological Survey.

a = Kimeridge Clay; *b* = Spilsby Sandstone; *c* = Tealby Clay; *d* = Tealby Sandstone; *e* = Carstone; *f* = Chalk; *g* = Glacial beds (mainly boulder clay).

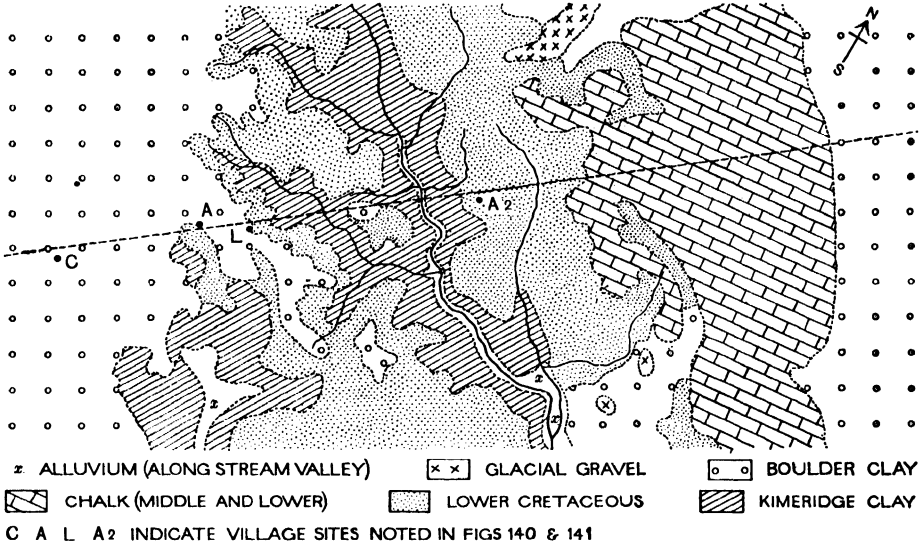


Fig. 142. Simplified Geological Map.

Based, by permission of the Director of the Geological Survey, on the one-inch geological map (drift edition).

Much help will be derived from *The Elements of Field Geology*, by G. W. Himus and G. S. Sweeting, Chapters IV to VIII dealing with Geological Mapping in an interesting and practical way, and Chapter X with the Interpretation of Geological Maps.

EXERCISES ON PART I

These exercises deal mainly with practical work connected with the study of maps. They are grouped into sections, at the head of which reference is made to chapters dealing with the subject of such sections.

Scale is important in map study, and thus several questions are devoted to the construction of scales and questions on their use.

Several questions, mainly on contoured maps, have been given as preliminary to questions based on actual Ordnance maps. The questions on contoured maps, as well as the maps themselves, are mainly, by kind permission of the Local Examinations Syndicate, Cambridge University, from various Cambridge School Certificate and Higher Certificate papers.

Many exhaustive questions are given on Ordnance maps reproduced by official sanction. Study of such maps is very important and exercises on them should be carefully worked.

Questions dealing with weather maps, general atlas maps, distributional maps, and map projections have practical bearing. The actual construction of distributional maps and graphs can be made from statistics in such publications as *Whitaker*, the *Statesman's Year Book*, etc. It is not desirable to load a book like this with statistics, but questions are given to test knowledge of the principles underlying construction of distributional maps. This is the form questions usually take in examinations, the actual construction of such maps being a rather lengthy process.

Scales

(*See* Chapter II.)

1. What are the Representative Fractions of the British Ordnance Maps on scales respectively one inch, half-inch, and quarter-inch to the mile?

What statements of scale in cm. to the Km. correspond to the above-mentioned maps?

2. Which is on the larger scale: the British one-inch Ordnance Map or the French 1 : 50,000 map? Give a brief reasoned answer in support of your statement.

3. Construct suitable scales in cm. to Km. for the maps mentioned in Question 1.

4. Draw suitable scales in inches to the mile and cm. to Km. for the International Map (1 : 1 million).

5. Find the Representative Fraction for each of the following scales: 5 ml. to 1 in., 5 in. to 1 ml., ½ cm. to 1 Km., 2 cm. to 1 Km., 5 in. to 1,000 links.

6. Construct a scale of 4 ml. to the in. to show half-miles, and one of 6 in. to the ml. to measure 1,000 yd.

7. A racing motorist, travelling at 90 ml. per hr., covers a straight length of road between two points, A and B, in 10 min. If the distance between A and B measures 5 in. on a map, what is the R.F. of this map? Give a reasoned answer, and construct a scale to show miles.

8. You are given a map, *x*, for some 40 sq. ml., showing the results of careful triangulation and systematic contouring. It is on a rather larger scale than 1 : 63,360 and considerably less than 1 : 10,560. If you have sheets of the one-inch and six-inch Ordnance Map of the same country, say how, by using either of these Ordnance Maps, you could ascertain the scale of the map *x*. Draw a suitable scale for it showing 1,000 yd. intervals.

9. To construct a time-scale, for, say a map of scale 1 in. to 1 ml., for a person walking 4 ml. per hr., note that 4 in. represent 4 ml. (covered in 1 hr.). Draw a line 4 in. long, bisect it and number the centre as "0" and the right-hand end as "30 min." The half of the line to the left of 0 can be divided into three equal parts, each representing 10 min. and numbered (right to left) 10, 20, 30 min.

Discuss the practical value of such a scale, and construct scales to show the distance traversed by an exploring party travelling 2½ ml. per hr., using maps of scale 1 : 50,000 and 1 : 63,360.

10. You have three maps respectively on a scale of 1 : 50,000, 1 : 63,360, 1 : 80,000 to represent parts of a region for which a map on a common scale of 1 : 60,000 is to be made. If sides of grid squares on the redrawn map are to be 1 in., what are they on the other maps? Give a reasoned answer.

Draw scales for the new map to show miles and Km. respectively.

Contoured and Physical Maps

(*See* Chapters V. and VI.)

The questions 1 6, 8, 13, 14, 15, 17 and relevant maps are taken from Cambridge School Certificate papers, and 19, 20 from Cambridge Higher Certificate papers by kind permission of the Local Examinations Syndicate of the University of Cambridge. Additional questions on the maps are also given. Maps are on a smaller scale than in the examination papers.

These questions are very useful as an introduction to the fuller analysis of Ordnance Survey Maps, such as the analysis given in Chapter VII.

Do not attempt merely to describe *the map*, but endeavour to see in three dimensions *what is behind the map*. Try to see mentally and to describe what the map signifies, and remember that the map is really a kind of geographical shorthand note of the actual country.

In addition to attempting the actual questions set on these maps, it is possible to use the maps for practice in interpreting details referred to in Chapters V., VI.

1. On the map (Fig. 143) given you, contours are drawn for every 250 ft.

(i) Draw in neatly (*a*) the course of the stream which enters the sea near A; (*b*) its chief tributaries.

(ii) What is the approximate height of the highest point of the island? Mark its position by an arrow.

(iii) Calculate the approximate scale of the map, and explain how your result is obtained.

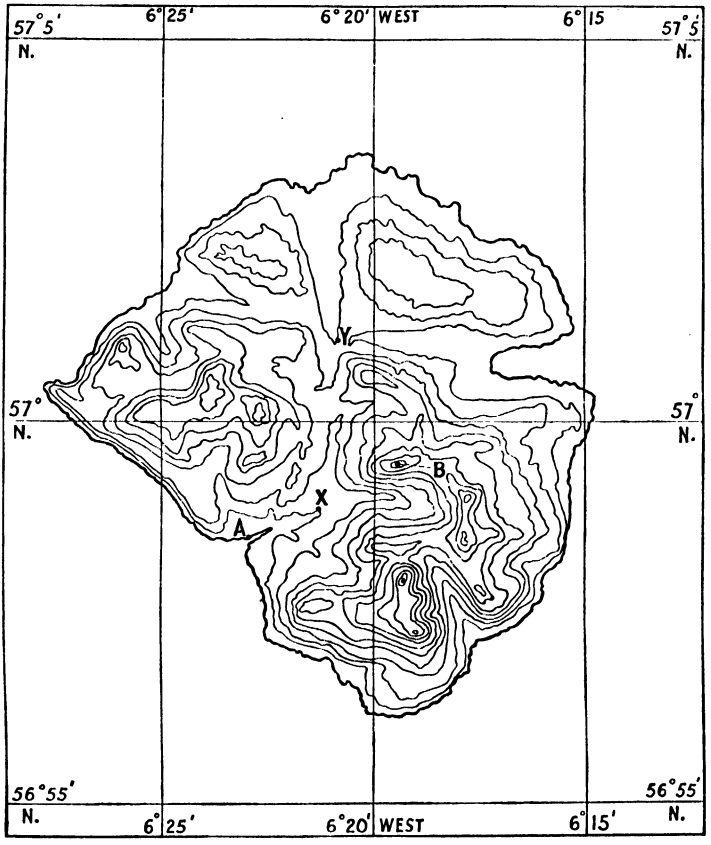


Fig. 143.

(iv) Calculate the average slope from B to X.

(v) Compare the view obtained from X with that from Y looking east in each case.

2. Enlarge the map (Fig. 143), say to twice the size, and draw the contours in pencil. Identify the valleys and trace in ink the course of probable streams.

3. Write notes on the physical characteristics of the valleys as suggested by the contours in Fig. 143, *e.g.* what you could learn from longitudinal and cross-sections, etc.

4. Identify features such as escarpment, spur, ridge, plateau, col in Fig. 143.

5. Suggest the types of scenery noticeable in a coasting voyage round the island. (Fig. 143.)

6. The map (Fig. 144) is drawn on the scale indicated below. Contours are drawn at 100 ft., at 200 ft., and upwards for every 200 ft.

(*a*) Shade lightly in pencil the parts between 800 and 1000 ft.

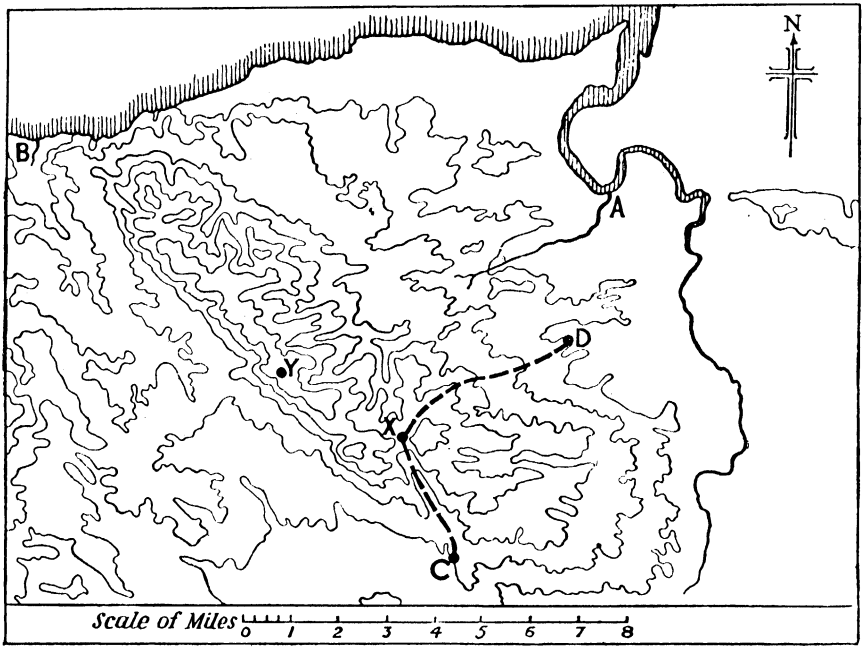


Fig. 144.

(*b*) Part of the course of a stream is shown flowing at A into the large estuary. Draw in from their sources the courses of the headwaters of this stream.

(*c*) Towards the N.W. of the map, the mouth of a stream is shown flowing into the sea at B. Draw in pencil the water-parting (*i.e.* the divide) of the basin of this stream, as far as it is shown on the map.

(*d*) *Either:* Compare the views to the east and to the west from the commanding position at Y. Remember that your field of vision is about 60°;

Or, Describe the direction and character of the small road, indicated by a broken line (- - - - -) from C to D, through X (750 ft.), and calculate the gradients in the steepest parts on either side of X.

7. In Fig. 144. (*a*) Identify the various physical features by means of the contours. (*b*) Describe the features associated with the large river flowing northward into the sea. (*c*) Describe the character of the coastal lands. (*d*) Compare the coastal plan with the flood-plain of the river noted in (*b*).

8. Study the map given in Fig. 145. It is contoured at vertical intervals of 100 ft., and shows all the surface streams of the area.

(*a*) Calculate the approximate area in square miles of the country shown on the map.

(*b*) Shade the parts more than 600 ft. above sea-level.

(*c*) Print the words "gap," "escarpment," and "dry valley" in their appropriate places on the map.

(*d*) Describe the chief features of the relief of the land.

(*e*) Two railways traverse this area, one from north to south, the other from west to east. Insert them on the map.

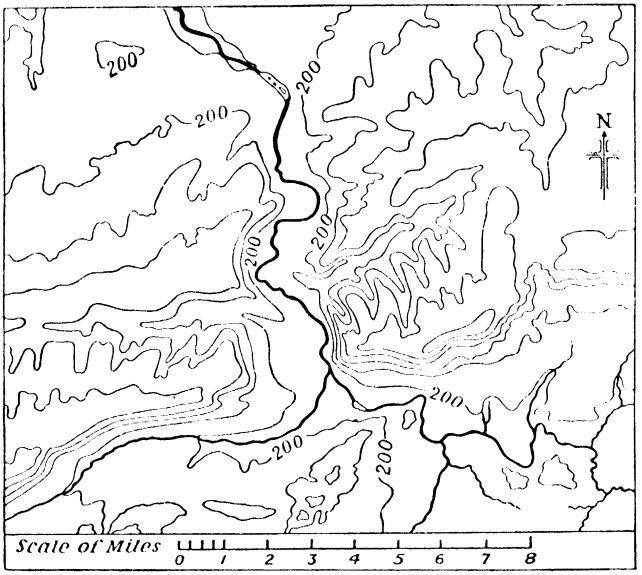


Fig. 145.

9. Describe the features associated with the river shown on the map (Fig. 145), and compare the character of the valley at different parts of its course.

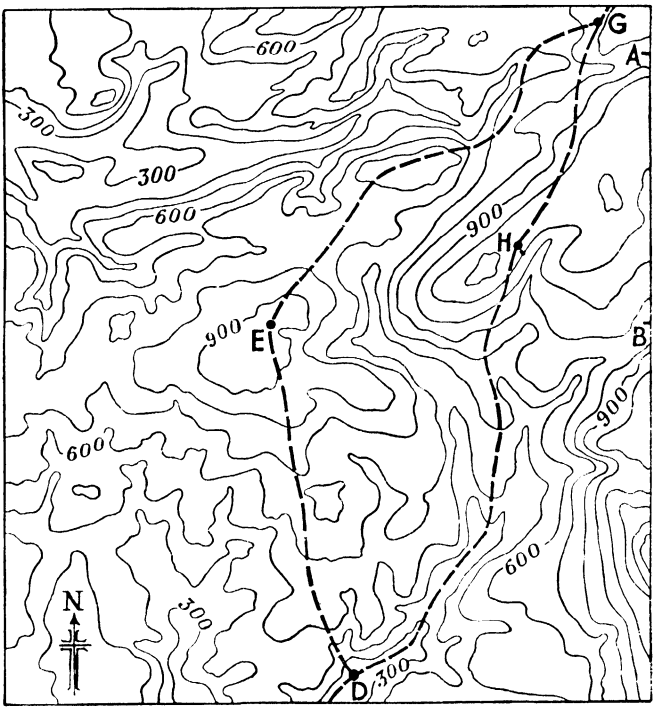
10. Compare the streams in the S.E. of Fig. 145 with that in the S.W., and make some comparison of the landscape likely to be seen in different parts of the region mapped.

11. Enlarge the map (Fig. 145) to three times its present size (see page 12), and draw three or four diagrams showing cross-sections of the valley at different points. Describe any differences in the type of valley shown by such sections.

12. Suggest where, on Fig. 145, village sites are, and are not, likely. Suggest any negative effect of the river on location of village sites and say what use would probably be made of the land in the main valley.

13. The area shown on the map (Fig. 146) is taken from a British Ordnance Map. The contours are drawn at intervals of 100 ft., and the dotted lines represent roads.

(i) On the map mark the following:—(*a*) A river flowing from B to the southern edge of the map, and *one* right-bank tributary. (*b*) *One* area of moorland and *one* area of meadowland; shade lightly these areas in different ways and print the words **Moor** and **Meadow** on the shading. (*c*) The road from D to G through E as a first-class road unfenced on both sides where it rises above 700 ft.



Scale 1 : 126,720

Scale (ii) (a) _____

feet
1000
800
600
400
200
0

(ii) (c) Distance in miles from D to G (via H) =

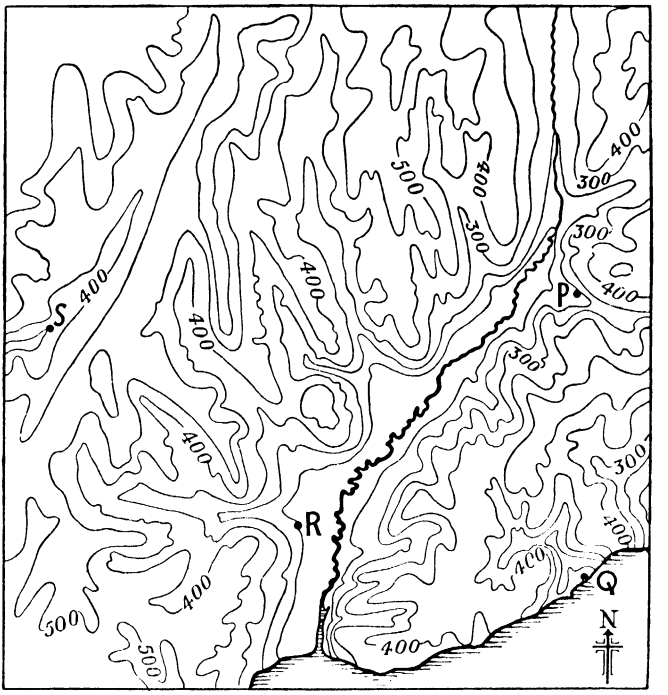
Fig. 146.

(ii) Under the map:—

(*a*) Divide the given line to show the scale of the map in miles.

(*b*) On the ruled lines, draw a section (or profile) of the road which runs from D to G through H, using the vertical scale which is marked at the side of the lines.

(*c*) State in miles the length of the road DHG.



Scale 1 : 126,720

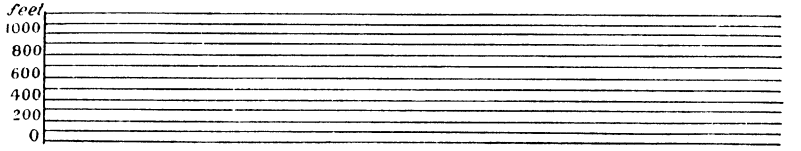


Fig. 147.

14. The map (Fig. 147) shows part of the South coast of England. The contours are drawn from sea-level at 100 ft. intervals. Examine the contours carefully and the positions of the points P, Q, R, S.

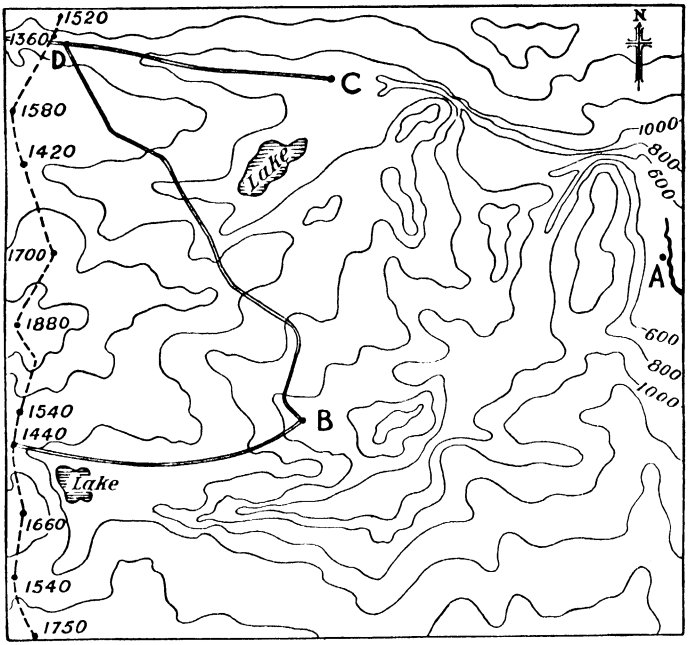
(*a*) Shade the areas which are 600 ft. and over.

(*b*) On the ruled lines draw a profile-section of the country along the line joining S and P.

(*c*) Draw two right-bank tributaries of the main river.

(*d*) Show the most likely track of a railway from Q through R to S, and mark tunnels.

(*e*) Show the watershed in the south-eastern portion of the map (south of P).



Scale 1 : 158,400

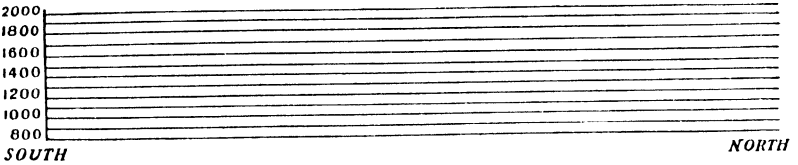


Fig. 148.

15. On the map (Fig. 148) find the towns A, B, C, and study the map-scale.

Contours are drawn at 200 ft. intervals, from 600 ft. upwards. The broken line marks the divide (*watershed*) of two river basins; altitudes along the divide are shown in feet.

Motor roads lead from B to C into the next river basin.

Draw on the map—(*a*) A straight line from A to the highest point of the divide, and along the line write (i) its direction from A; (ii) the distance, to the nearest $\frac{1}{4}$ ml., which the line represents. (*b*) *From their sources*, the headstreams of the river on which A is situated. (*c*) A motor road *with easy gradients* between A and B, and also a branch of that road to C. (*d*) A profile-section along the divide from South to North.

16. Consider Fig. 148 and—

(*a*) Describe generally the relief and write notes on the more important physical features.

(*b*) Suggest broad physical divisions.

17. Study the map (Fig. 149). The contour intervals are 100 ft. The figures near X and Y give the height in feet of the river at these points.

Two roads, A to B and C to D, cross the region.

(*a*) Shade the parts over 800 ft.

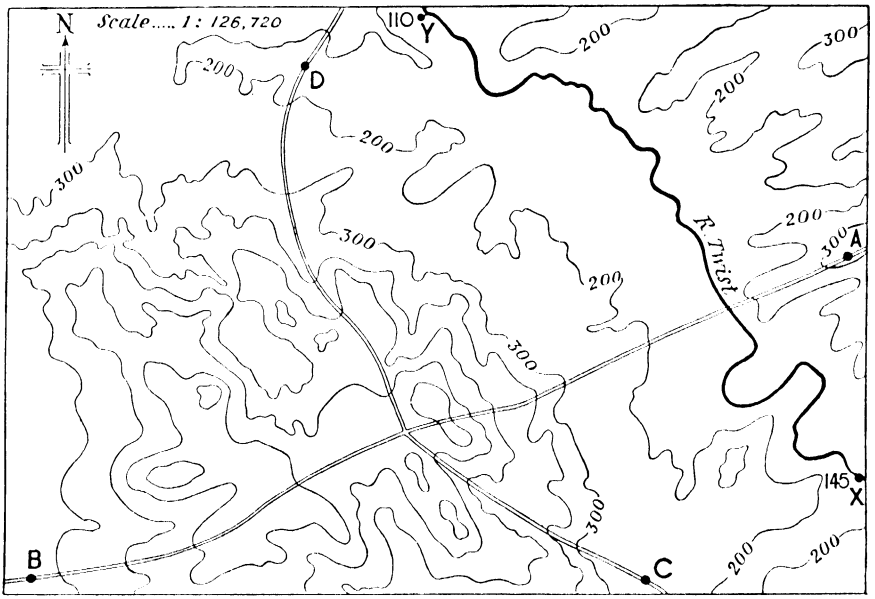


Fig. 149.

(*b*) Measure the distance *by river* from X to Y, and find the average fall of the river *expressed in inches per mile.*

(*c*) In what *general* direction is the river flowing ?

(*d*) Describe *in detail* the course of the road from A to B. How does it differ from that of the road from C to D ?

18. Consider Fig. 149 and—

(*a*) Describe generally the relief and write notes on the more important physical features.

(*b*) Suggest broad physical divisions.

19. Compare the coast-lines shown on the accompanying maps (Fig. 150). Describe and explain their characteristic features.

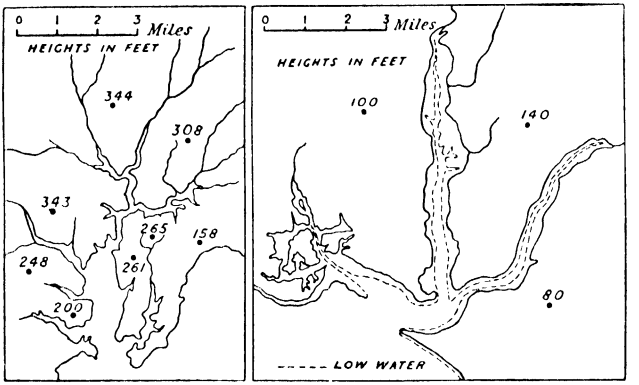


Fig. 150.

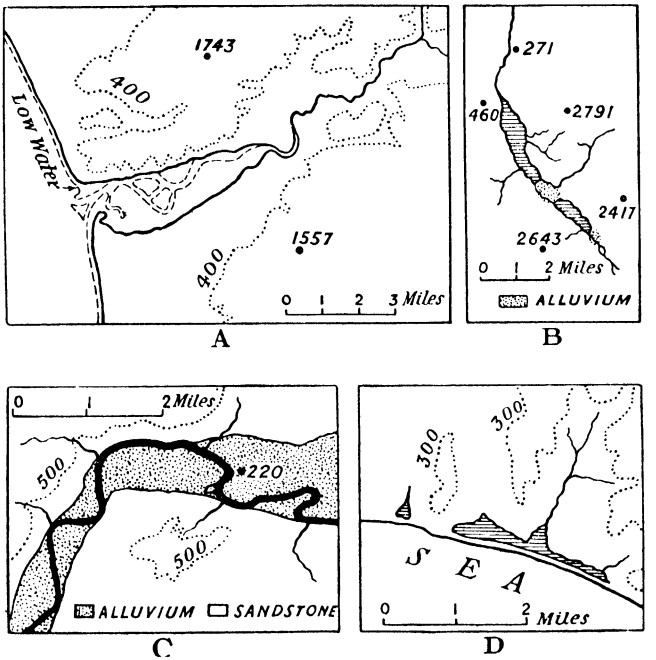


Fig. 151.

20. Describe and explain the physical features of the regions represented on the maps (A–D) (Fig. 151.).

What change would take place in C if the region were slowly uplifted ?

21. Study Fig. 146.

(*a*) Identify features such as escarpment, valley, spur, ridge.

(*b*) Attempt a general description of the relief and physical features as suggested by the contours.

(*c*) Suggest two or three distinctive physical regions, *e.g.* river basin, dissected plateau, etc.

22. Consider Fig. 147 and—

(*a*) Identify features such as escarpment, valley, spur, ridge.

(*b*) Attempt a general description of the relief and physical features as suggested by the contours.

(*c*) Suggest two or three distinctive physical regions, *e.g.* river basin, dissected plateau, etc,

(*d*) Describe the coastland.

(*e*) State what is noteworthy in the course of the river flowing from N. to S. in the eastern part of the map.

Ordnance Maps

(*See* Chapters IV.–VII.)

The following questions 1 to 20 are based on the Tourist Edition of the Lake District map, which is required, but most of them can be adapted for use with any other Ordnance Map.

Suitable maps for study are sheets dealing with—

(*a*) The Pennines, Cotswolds, Chilterns, Downs, Lincoln Edge, Lincolnshire and Yorkshire Wolds.

(*b*) North Wales, Highland and Southern Uplands of Scotland (especially river valleys of such regions).

(*c*) Cornwall and Devon, especially Dartmoor, Exmoor.

(*d*) Fenland, Vale of Pickering, Weald, Lower Trent Valley, Vale of York.

(*e*) Coasts of Holderness, S.E. Suffolk and Essex, Kent and Sussex, Cornwall–Devon, W. Scotland, Moray Firth.

A suitable selection can be made from the Index Sheet of the one-inch Ordnance Maps. It is advisable (1) to study carefully examples of maps representing different types of country, and (2) to analyse them on lines suggested by the following questions:—

1. Reducing the scale to 5 ml. to 1 in., draw sketch-maps showing—
   (*a*) Distribution of woodland, and account for its presence.
   (*b*) Lakes and streams, noting what features in the original are necessarily distorted.
   (*c*) Routes and towns, explaining how far the sites of the towns seem to be influenced by physical features.
2. Adopting a scale of 6 in. to 1 ml., enlarge portions of the map as follows:—
   (*a*) Districts (say about 10 or 12 sq. ml.) immediately around (i) Skiddaw, (ii) Helvellyn, (iii) Scafell, noting what may be deduced from the contours and analysing character of the slopes.
   (*b*) District covered by squares F1, F2, F3 on the grid (Buttermere, etc.), writing brief notes on the physical features.
3. Reducing the scale to 4 ml. to 1 in., draw sketch-map showing—
   (*a*) The relief simplified. (*b*) The drainage.
4. Use the above sketch-maps to suggest possible division into physical (or physiographic) regions, justifying such division.
5. In connection with the map required in 3 (*a*), explain the method adopted for showing the simplified relief features. Why is it difficult to reduce the map literally in this respect?
6. On a reduced sketch-map (scale 4 ml. to 1 in.) show the distribution of villages by a small circle and towns by a square.
7. Discuss broadly the general distribution of population shown on this map, and explain clearly why the blanks occur.
8. With the aid of a sketch-map of scale 4 ml. to 1 in., explain how far the area is served by (i) first-class, (ii) second- and third-class, roads, and account for the occurrence of these different types of road.
9. Draw sections true to horizontal scale, and with the least possible exaggeration of vertical scale for country indicated by a straight line between the following places:—
   (*a*) Ambleside and Windermere.
   (*b*) Buttermere to Borrowdale.
   (*c*) Great Dod (D7) to Barton Fell (D10).

10. Describe character of country shown by the above sections.

11. Draw longitudinal sections of the roads from—

(*a*) Kendal to Bowness-on-Windermere.
(*b*) Kendal to the township of Windermere.
(*c*) Coniston to Ambleside.

12. Compare the character of the above roads, giving reasons for any striking differences.

13. Draw sketch-maps of the following lakes on a scale of 6 in. to 1 ml., and include sufficient contours to show the relief of the lakeside regions:—

(*a*) Hawes Water. (*b*) Coniston Water.
(*c*) Wast Water. (*d*) Ullswater.
(*e*) Thirlmere. (*f*) Crummock Water with Buttermere.

14. Similarly draw maps on scale of 3 in. to 1 ml. for—

(*a*) Windermere.
(*b*) Derwentwater with Bassenthwaite.

15. Analyse the maps drawn under 13 and 14 in an endeavour to describe the general features of the various lake basins of the Lake District.

16. Taking Trout Beck flowing into the eastern side of Windermere, draw an enlarged sketch-map on scale of 6 in. to 1 ml., showing the contours. Then draw about half-a-dozen cross-sections of the valley, and, using them, discuss the physical character of the valley.

17. Draw, based on this map, contoured sketches on an enlarged scale of 6 in. to 1 ml to show (i) a hanging valley; (ii) a col; (iii) a re-entrant; (iv) a spur; (v) a scarped slope; (vi) a cirque; (vii) a rounded hill; (viii) portion of dome with radial drainage.

18. Analyse the place names, *e.g.* pike, fell, to illustrate the general character of the physical features.

19. Select from the region (i) a main valley floor; (ii) a lakeside plain or border; (iii) a lofty summit; (iv) a moderately high plateau; and describe the general character of the landscape as seen from your position.

20. Co-ordinate what you have deduced in connection with Question 19 and give a summary account of the landscape associated with the Lake District.

21. For each of the small maps for Keswick (page 64), Sedbergh (page 64), Banchory (page 32), Cheddar (page 32), apply from the above exercises the following questions: 1, 3, 4, 6, 7, 8. Contrast the physical features and relief of the Banchory and Cheddar maps, briefly noting their probable effect on human occupations.

22. Describe and compare the methods of showing relief on any topographical maps known to you.

Note.—The British quarter-inch and one-inch Ordnance Maps, and various editions of the one-inch Ordnance Map offer scope for this question.

23. Write a short essay on the usefulness and the limitations of contours for showing relief, illustrating in the latter respect from maps for regions such as the Scottish Highlands and the English Fenland.

24. Describe and comment upon the conventional methods used on English large-scale topographical maps for indicating communications and features connected with them.

25. Describe the various symbols used in connection with "Man and his Work" on the one-inch (Popular Edition) of the English Ordnance Map. Note any improvement in the Symbols of the Fifth (Relief) edition.

26. For what special purpose in the study of physical geography do you think the following English Ordnance Maps are useful: quarter-inch, half-inch, and one-inch to the mile respectively? Suggest how any of the above maps may be misleading for this particular purpose.

27. Answer similarly for the economic geography dealing with occupations and trades.

Map Drawing from Data

(*See* Chapters V.–VII.)

1. Make sketch-maps with suitable land and sea contours to show the following on a scale of 2 ml. to 1 in.:—

(i) A low sandy dune-bordered shore line, with drowned valley estuaries and fringed with low islands. Along the coast the hinterland is flat plain, rising inland to undulating country and finally to chalk upland parallel to the coast and forming a dissected plateau with scarped side furthest from the coast.

(ii) A drowned coast, with fjords and tributaries, fringed by a skerryguard of islands. The land is essentially a plateau about 3,000 ft. high, dissected by drainage emptying into the fjord.

(iii) Two roughly parallel east-west ranges of chalk hills about 900-1,000 ft. high, with an intervening lowland about 30 ml. wide along which run low hills of sandstone parallel to the chalk ranges. Streams rise on either side of the sandstone ridge and flow towards the chalk, through which they pass by narrow gap valleys to join a large river and the sea-coast respectively north and south of this upland region.

2. Draw, stating your scale, contoured sketch-maps to show—

(i) A stretch of inland country about 40 ml. by 30, consisting essentially of chalk uplands with a well-developed escarpment from which streams flow to a bordering lowland. On the upland show examples of ridge and plateau, and give an example of a wind gap. Two consequent streams flow along the gentler slope and unite on the adjacent plain.

(ii) An area of about 50 ml. by 60 showing an alternation of rocky peninsulas and long, narrow openings (rias), the hinterland being an upland plateau dissected by valleys whose streams flow into the rias.

(iii) An island about 40 miles long from S.W. to N.E. and varying in breadth from about 30 miles in the S.W. to 10 miles in the N.E. The S.W. coast is much dissected with long, narrow, fjord-like openings and is fringed by a number of small rocky islands. From this coast the land gradually rises to a plateau some 2000 ft. high and stretching through about a third of the length of the island. The plateau descends to a low undulating plain about 15 miles long by 12 miles broad. From the plain a range of hills rises to the N.E. and is flanked by a coastal plain about 5 miles wide. From these hills rivers flow to both plains, and also from the plateau to the larger plain. The plateau is of limestone, and the hills, which are of chalk, run down to the coast in the N.E. to form cliffs. Much of the smaller coastal plain is marsh, but the larger plain into which two estuaries open, consists mainly of well drained land on which alluvium predominates. In addition to relief, show drainage features, possible sites of human settlement, and lines of communication.

Weather and Climate Maps

(*See* Chapters IX. and X.)

The questions 1, 7, 8, 10, 11 are taken from Cambridge School Certificate papers, 9, 15, 23, 25 from Cambridge Higher Certificate papers, and 24 from Cambridge General Certificate of Education (Advanced Level) paper, by kind permission of the Local Examinations Syndicate of the University of Cambridge.

Questions 18, 19, 20, 21, 22 are from papers set for the Intermediate Examinations in Arts and Science of the University of London and are reproduced by kind permission of the Senate.

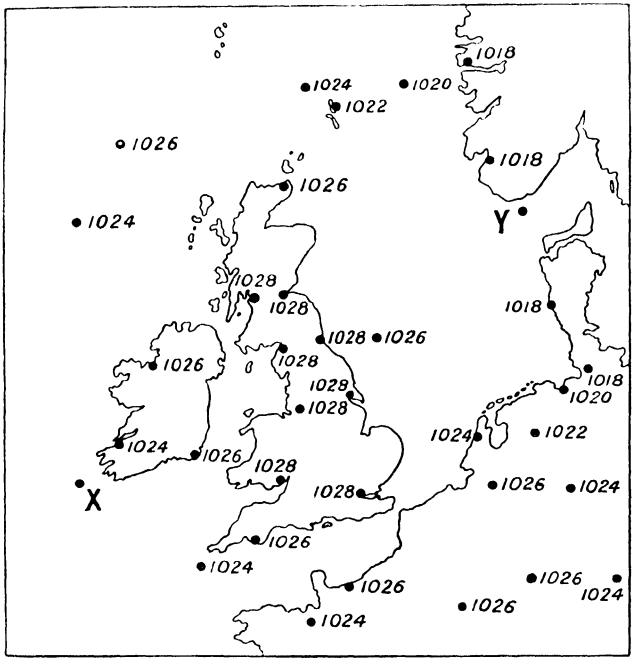


Fig. 152.

1. Study the map (Fig. 152) which records, on a day in late November the corrected barometric pressures at certain land stations and ship positions.

(*a*) Join with neat lines all stations having the same pressures. What name is given to these lines?

(*b*) Draw a graph to show the variations of pressure along the line X-Y.

(*c*) Describe the distribution of pressure as indicated by the chart.

2. Explain why the maps (Figs. 44-57) given in Chapter IX. would be of relatively little use in explaining the *climate* of the British Isles, though they illustrate several types of British *weather*.

3. Write a short account of the climate of the British Isles, and suggest types of diagrams or maps which might be used as illustrations.

4. In what way does an isotherm map or an isobar map (*a*) resemble, (*b*) differ from, a contoured map? What adjustment of data is usual before preparation of isotherm and isobar maps? Criticise such adjustment.

5. What data, not necessarily rainfall statistics, would you require for preparation of (*a*) a rainfall graph, (*b*) a rainfall map? How could the graph be made auxiliary to the map?

6. Analyse a typical weather map to show (*a*) what information can be derived from it; (*b*) what data would be required for its preparation.

7. On the map (Fig. 153) the isotherms are drawn for mean sea-level temperatures in degrees Fahrenheit.

(*a*) On the map, shade the area in Ireland where the mean sea-level temperature for January is highest and the area in England where it is lowest.

(*b*) State, to the nearest degree, the mean temperature at A in July and at B in January. Explain how you obtain your answers.

(*c*) Explain the irregularities in the July isotherm 60° F. and in the January isotherm 32° F. respectively.

8. Study the Weather Charts in Fig. 155 and notice the dates.

(*a*) What does *mb* stand for, and what is the value of 1 *mb* in inches?

(*b*) Show, by arrows in each chart, the direction of the wind on the N.E. coast of Scotland and on the N.W. coast of France.

(*c*) Describe the pressure changes which took place in the 24 hours.

(*d*) How would these changes have affected the weather in S.W. England?

9. Give a general account of the weather which would be likely to occur under the conditions shown on the barometric charts given in Fig. 154. Indicate on the maps the directions of the winds.

10. The map (Fig. 156) shows the corrected readings of the barometer, in millibars, at a number of observation points in Western Europe at 7 a.m. on a certain morning in March.

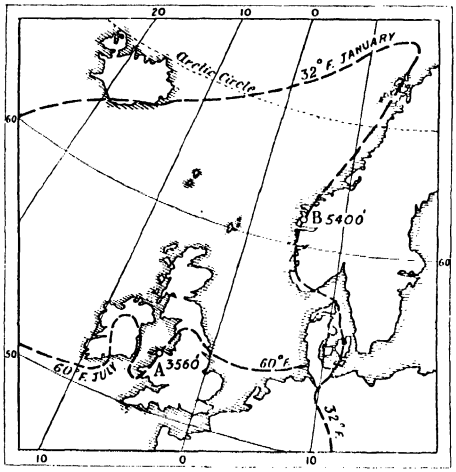


Fig. 153.

(*a*) Draw the isobars of 990, 995, 1,000, and 1,005 mb.

(*b*) Indicate by arrows the probable direction of the wind over Western Ireland, Southern England, Denmark, the Shetland Islands.

(*c*) How did you decide in which direction to point the arrows when answering (*b*)?

(*d*) Describe the distribution of pressure shown on the map.

11. The map (Fig. 157) shows the distribution of atmospheric pressure over Western Europe at 7 a.m. on a certain November day.

(*a*) Explain the significance of the words **High** and **Low** which are printed on the map.

(*b*) Indicate by arrows the probable direction of the wind over N.W. Ireland, N. Scotland, N. Coast of Spain, and Denmark.

(*c*) Shade lightly the areas where rain would probably fall during the day.

(*d*) How would the weather experienced during the day in S.E. England differ from that experienced in Southern Spain?

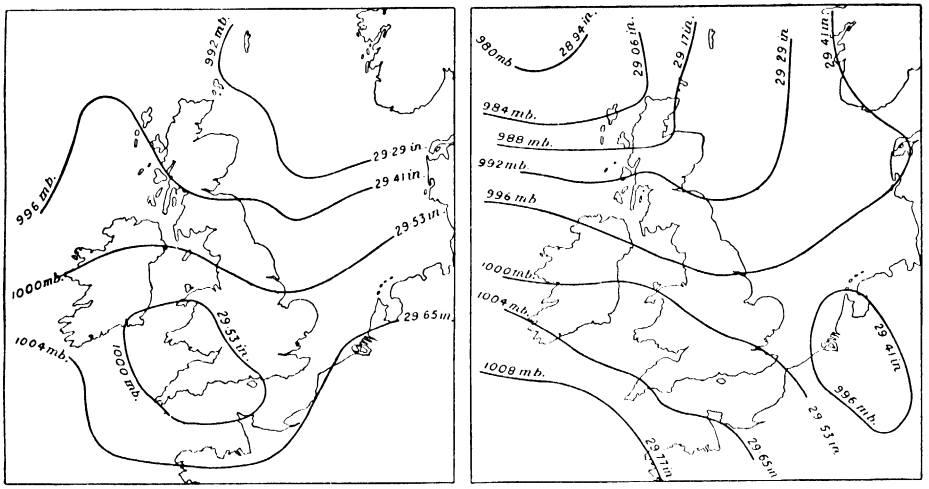


Fig. 154.

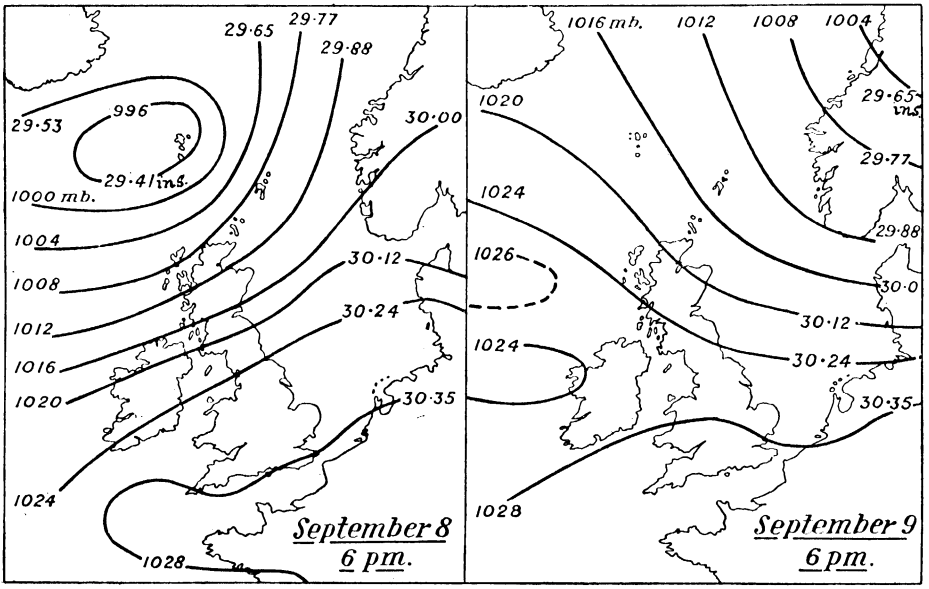


Fig. 155.

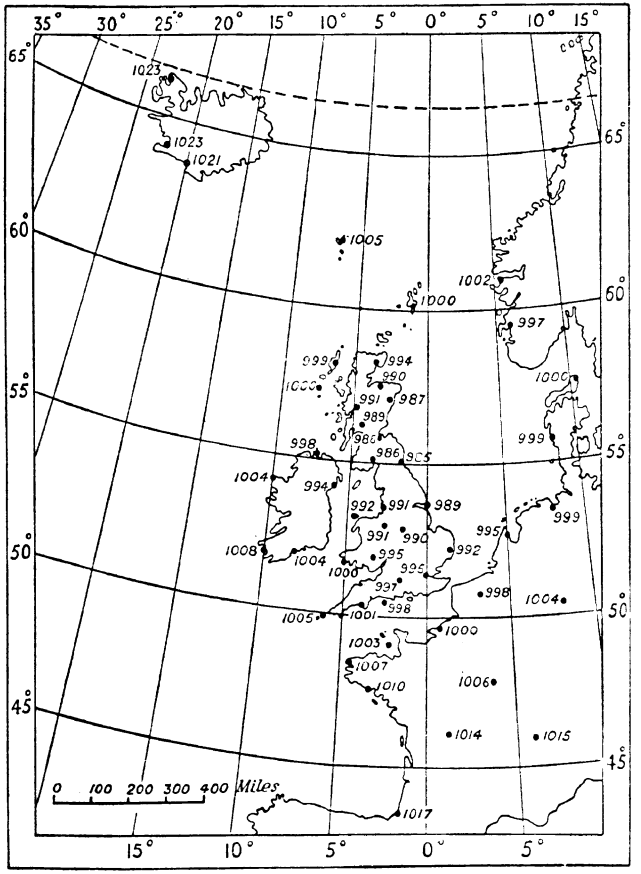


Fig. 156.

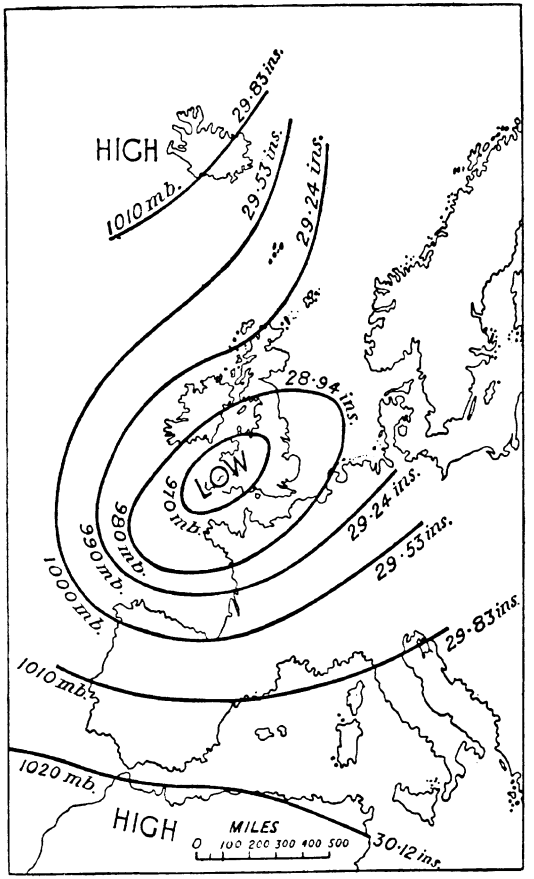


Fig. 157.

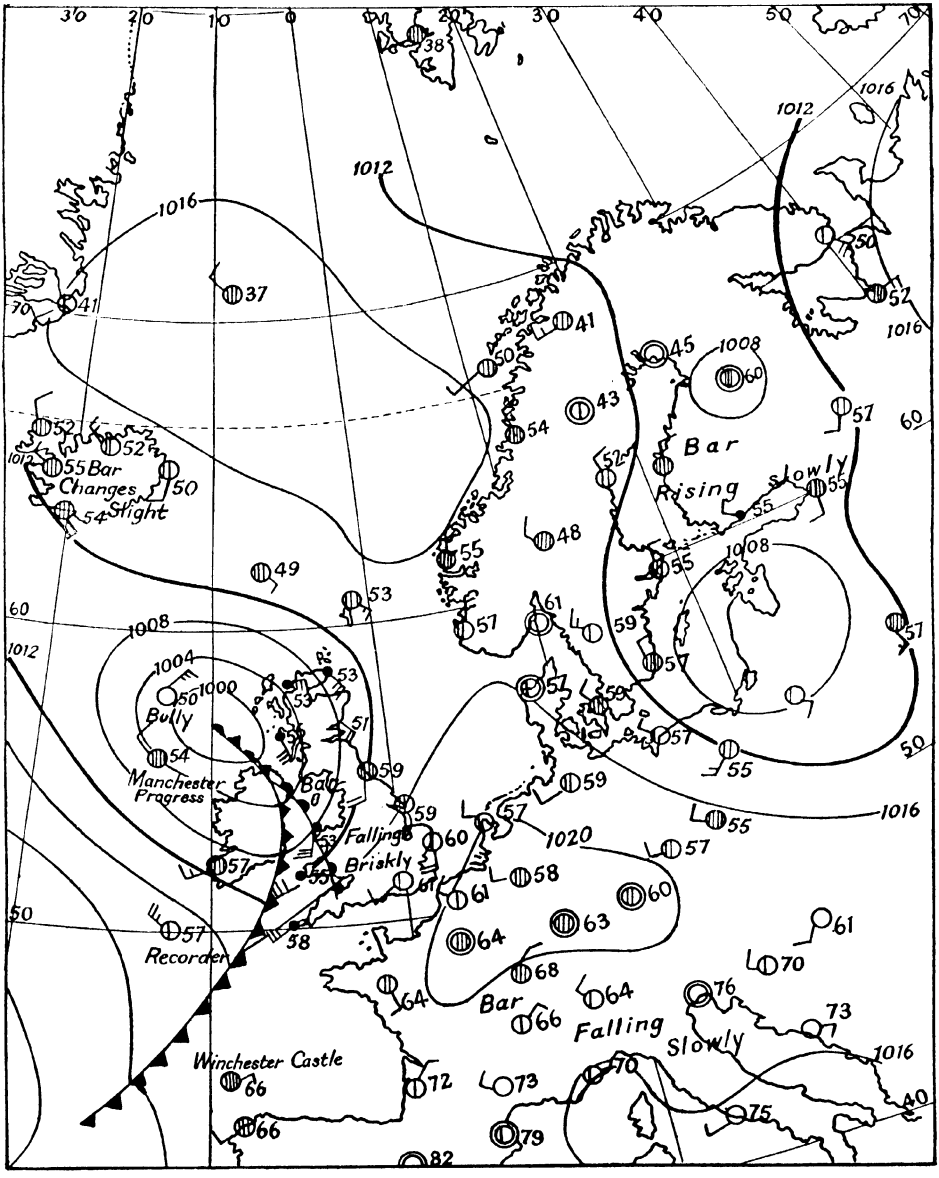


Fig. 158. The Evening of Thursday, 12th September 1946, at 18h. G.M.T.

12. On the weather maps (Figs. 46-57) comment on the direction of the main air currents and compare them with the conventional planetary wind system.

13. Write a short essay on the methods of weather forecasting, and note what unforeseen factors may possibly interfere with the forecast.

14. Compare any two maps showing the weather conditions associated with depressions and anticyclones (*a*) in winter, (*b*) in summer.

15. (*a*) On the chart provided (Fig. 158) name the different types of pressure systems and fronts shown.

(*b*) State, from the evidence on the map, the general weather conditions over Western Ireland, Central Scotland, and the Paris Basin.

(*c*) Give the maximum and minimum wind speed (in miles per hour) over the British Isles.

16. What weather system does each of the maps (Figs. 159, 160) typify? Describe the general conditions associated with such systems, and give reasons for any special features.

17. Reckon the gradient from A to B and C to D on diagram 161, and indicate the probable direction of the dominant winds in the area covered by the isobars.

18. On the accompanying weather map (Fig. 162) indicate by appropriate symbols:—

(*a*) Wind speeds and directions at ten carefully selected stations.

(*b*) A warm and a cold front on the surface.

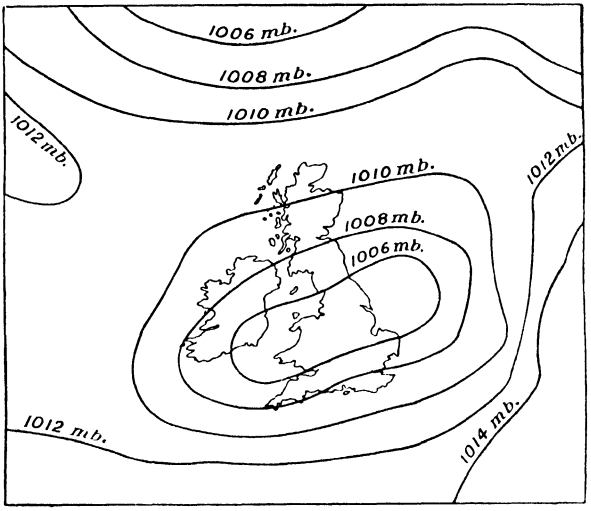


Fig. 159.

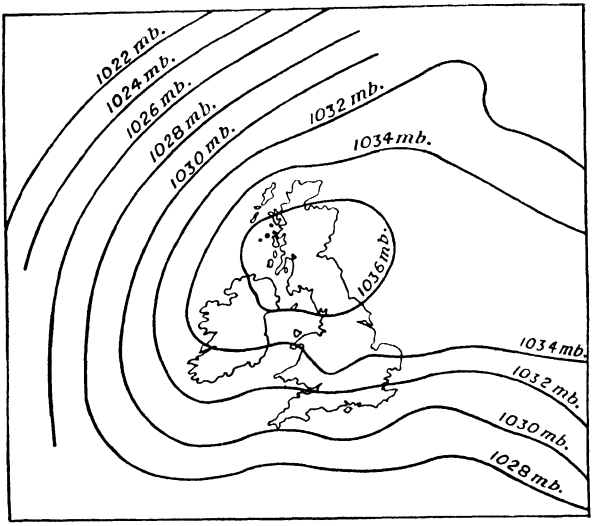


Fig. 160.

Give a general description of the weather in the area of the British Isles and Germany and shade the zone of probable rain.

19. Draw a general diagrammatic map showing by numbered isobars four distinct isobar configurations or "weather types" associated together. For any *one* such type describe the probable conditions of wind and weather.

20. Using the customary symbols, prepare a sketch synoptic weather chart to show a cold front and a line of occlusion over Britain in December. Write a short note on the temperature distribution.

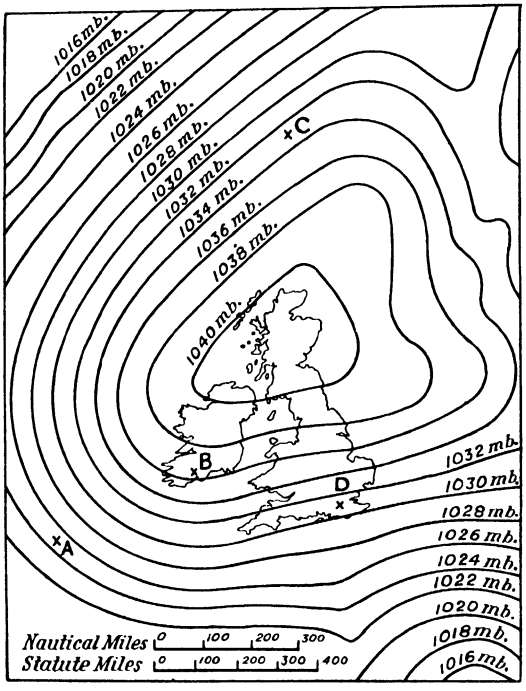


Fig. 161.

21. Draw a weather map with isobars to show a wedge of high pressure separating a deep depression to the north-west from a weaker depression to the south-east. Insert indications of wind directions, cloudiness and rainfall, using customary symbols.

22. On an outline map, indicate a depression in an advanced stage of occlusion centred over the English Channel in spring. By means of appropriate conventional symbols, show the weather being experienced at eight stations within the system and briefly explain the chief features of the weather distribution shown.

23. Describe the probable pressure distributions associated with the following types of British weather—(i) a long spell of winter frost, (ii) strong south-westerly gales, (iii) an isolated fine interval during a period of rainy and unsettled weather. Illustrate your answer with simple weather maps.

24. Describe a possible distribution of pressure over the British Isles associated with each of the following types of weather—(*a*) a "heat-wave," (*b*) a "rainy spell," (*c*) "south-westerly gales." Draw simple synoptic charts to illustrate your answer.

25. On the map given in Fig. 163, which shows isotherms for January and July, draw lines of equal annual range of temperature. Comment on any points of special interest.

Map Projections

(*See* Chapters XI.-XIII.)

1. What would guide you in determining whether an atlas map of the world was on the Mercator or the Mollweide projection?

2. Give instances in connection with world maps for which the Mercator and Mollweide projections would be (i) suitable, (ii) unsuitable, stating reasons.

3. Why might a Mercator map be fairly suitable for showing world distribution of rice or rubber, but not of wheat? Suggest, giving your reasons, a better projection for rice or rubber distribution.

4. How would you recognise a zenithal projection from a general inspection? Name some of the chief zenithal projections and give their main characteristics.

5. For what types of map might some of the better-known zenithal projections be used? Mention briefly some of the limitations of this class of projection.

6. Which should you prefer for a world map to show relief features: the Sanson-Flamsteed or Mollweide projection? Give reasons.

7. Point out the usefulness of the following projections for specific purposes: Bonne, Simple Conical with one standard parallel, Conical with two standard parallels.

8. What projections would you use for Africa and South America (i) to emphasise orthomorphism, *i.e.* correct shape, (ii) to show distribution of rubber, cotton, and wheat? Give reasons for your choice.

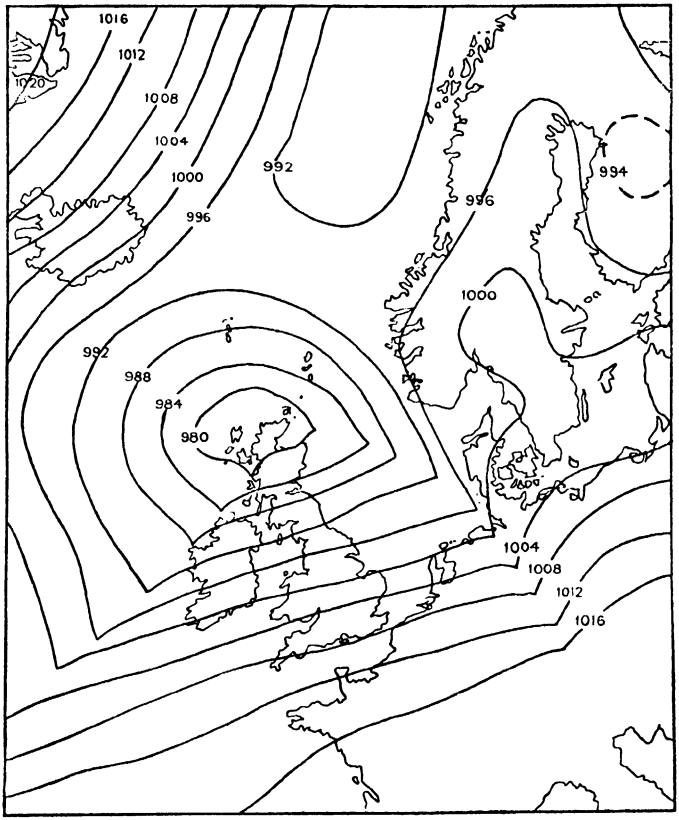


Fig. 162.

9. What projections would you select to show (i) route of the Canadian Pacific Railway, (ii) the Mississippi basin, (iii) prevailing winds and ocean currents of the Atlantic and Pacific Oceans? Give reasons.

10. Say why you consider the following projections would be unsuitable, viz. (i) Mercator for Canada, (ii) Sanson-Flamsteed for Australia, (iii) Bonne for Eurasia (*i.e.* Europe plus Asia), (iv) the Simple Conic with one standard parallel for South America.

11. Compare and contrast the properties of Conical and Cylindrical projections. Mention, giving your reasons, one region for which each is, and is not, suitable.

General Atlas Maps

1. In connection with Atlas maps, mention the contour intervals you have seen used for maps of (1) the World; (2) a continent like Africa or South America: (3) England and Wales; (4) France; (5) Switzerland; (6) India.

In each case suggest the type of features which the contours are designed to show. In what way do the relief features of these maps differ from those of large-scale topographical maps?

2. What do you understand by (i) a physical or physiographical region; (ii) a climatic region; (iii) a natural region? To what extent would your ordinary atlas maps be useful in determining such regions for (i) a given country; (ii) a continent?

3. To what extent do you consider that a small-scale atlas map gives an erroneous or, a limited impression of the relief of a continent? In this respect compare an atlas map of North America with the topographical maps on a scale of 1 : 50,000 for, say, the Western Highlands in Oregon and Washington.

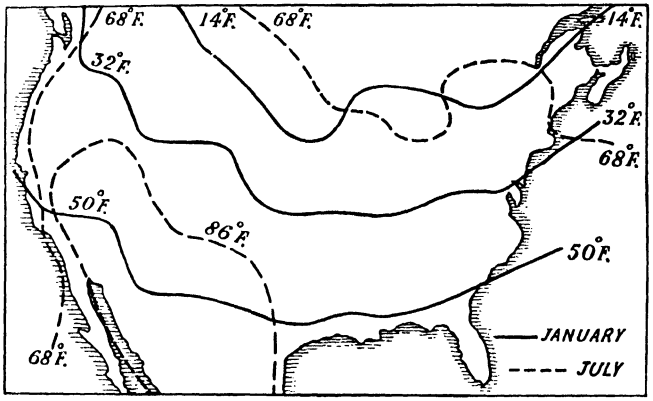


Fig. 163.

4. In connection with any atlases with which you are familiar mention what material it contains which will help you to—

(i) Explain the distribution of population in England and Wales.

(ii) Suggest broad climatic regions for a continent like North or South America.

5. Compare the ordinary climatic maps of a good school atlas with the weather maps issued by the Meteorological Office. Bring out differences as regards content and symbols used, and suggest for what particular purpose each type of map is intended.

6. How would you use reasonably good atlas maps to help you in describing the connection between physical features and routes in Switzerland and France? Which do you consider the more directly useful for this purpose and why?

Distribution Maps

(*See* Chapter VIII)

1. You have for a certain region—

(i) A table showing the number of sheep per parish.

(ii) Two distribution maps made respectively on the shading and dot method.

(iii) A graph curve showing comparatively the number of sheep per parish.

Arrange the above in the order of what you deem to be their usefulness, giving reasons for your choice.

2. Treat, in like manner, similar data bearing upon the population of (*a*) Yorkshire, (*b*) Lincolnshire, (*c*) Cornwall, and say what factors here come in which do not concern us in data for crops and cattle.

N.B.—Treat each county as for a separate question and note any points connected with the distribution of population in each county.

3. Say how you would use an atlas vegetation map in connection with relief and climate maps of South America to suggest a division of that continent into broad natural regions? How may the vegetation map, if used alone, give a false or one-sided impression?

4. Describe the methods adopted for collecting data relative to the number and distribution of cattle and sheep in England and Wales. How can the available data be used for mapping the distribution of such stock? How far do you consider that such data and the maps which can be made from them fail to represent the normal distribution of stock in this country?

5. What are the chief difficulties and problems involved in the compilation of a population map (*a*) of England and Wales for reduction to a scale suitable for atlas purposes; (*b*) of a limited area, say a county or part of a large county on a scale of 1 : 63,360 for illustration of a regional essay? Suggest ways of overcoming or minimising such difficulties.

6. What are the chief difficulties as regards data for, and preparation of, maps to indicate temperature? Comment on the limitations of temperature maps.

7. Explain, with illustrative sketches, how you would represent by diagrammatic or cartographical methods —

(*a*) Variability of rainfall and temperature for a certain station for a period of 20 years.

(*b*) Variability of population for a town and for a county as indicated by the figures for two separate census years.

Point out any special difficulties in connection with the use and adjustment of the available data, and say how you would overcome them.

Note.—(*a*) and (*b*) above can be regarded as separate questions.

8. Describe and criticise any cartographical methods you have seen in atlas maps and textbook diagrams designed to show density of population.

9. What types of map sometimes used to indicate density of population or stock fail to show adequately its distribution? Give reasons for such failure and suggest a remedy.

10. What data would you need to make a rainfall map of, say, England north of the Mersey and Humber? Given this data, explain how you would produce such a map. Note its limitations.

EXERCISES ON PART II

Most of Part II. deals with practical surveying as applied to map making. The best exercise after having seen, handled, and mastered the use of the various instruments, is to undertake some practical outdoor work with the instruments. Students in the Geography School of a University can normally obtain practice under expert guidance. Others must rely upon vacation courses, private help from surveyors, or upon their own resources. It is mainly for the latter that the following exercises are drawn up. To attempt them will give a concrete basis to what has been read in the various chapters.

The exercises are not graded in order of difficulty. The figures after each question refer to the various chapters containing relevant material.

No specific exercises are given on Geological Maps. Students are advised to select suitable maps, (1) to explain the physical features by the rock structure, (2) to study the sections on the maps with a view to drawing others similar to them elsewhere across the map.

1. Enumerate and emphasise the relative importance of the various stages necessary in the trigonometrical survey of a large area such as the British Isles. (Chapter XIV.)

2. A suitable base-line having been determined, describe, with illustrative sketches, the simple triangulation of an island of, say, 5,000 sq. ml. area, when the mean sea-level is known, but no previously computated trigonometrical heights are available. (Chapter XIV.)

3. Suppose an island such as Tasmania, with about 26,000 sq. ml. area, had not been surveyed previously, and that it was desired to make a topographical survey, reasonably careful, but not of minute geodetic accuracy. The aim is to make a reliable topographical map mainly by means of careful theodolite triangulation, supplemented by plane-table work. Enumerate the various steps in such a survey and comment upon their importance. (Chapters XIV.–XVII.)

4. As separate questions, select each of the steps enumerated in the previous answer, and describe the procedure in some detail. (A good atlas map of Tasmania will be of assistance in framing these answers). (Chapters XIV.–XVII.)

5. Make a list of the various instruments and accessories you would consider necessary in such a survey as that referred to in Question 3, and add brief notes why you consider each one suitable for the particular purpose in view. (Chapters XIV.–XVII.)

6. It is desired to make, for a large-scale map of 1 : 5,000, a topographical survey of about 30 sq. ml. around a village in one of the East Pennine dales. Outline the method you would follow in such a survey, supposing that the relevant one-inch Ordnance Map of the district was available. How would your map differ from the Ordnance Map mentioned ? (Chapters XV.–XVII.)

7. A tropical country has been covered by triangulation in a careful trigonometrical survey. It is desired to fill in topographical detail in (1) a wide alluvial plain watered by several rivers and mainly devoted to rice culture; (2) upland bordering the plain and rather densely forested. Explain how you would fill in topographical detail in the two regions, and for this particular purpose compare the usefulness of survey by (*a*) plane-table; (*b*) chain and staves. (Chapters XV. and XVII.)

8. Describe some form of prismatic compass so as to bring out the principles underlying the use of this instrument. Say how far it could be used in the survey of a small estate consisting of some woodland and three or four fields whose area varies from 5 to 10 acres. (Chapter XVI.)

9. Describe the essential principles of some form of clinometer and explain its use by indicating how you would contour the slopes of a rather deep and relatively narrow valley such as might be found in limestone country. (Chapter XVII.)

10. Describe the essentials of the " Indian " clinometer in comparison with clinometers of other types. Show how its advantages are apparent in the detailed topographical survey of a small stretch of hilly country where a framework of trigonometrical stations has previously been obtained by triangulation. (Chapter XVII.)

11. Describe, with illustrative sketch, the mapping of a park of about 100 acres, with woods at the S.W. and N.E. corners, and a stream, crossed by three bridges, flowing from N.W. to S.E. Roads cross the park from the S. and E. sides. There is a lodge at the E. gate, and a mansion, with chauffeur's cottage, is situated about the centre of the park.

(In this answer, no *detailed* description need be given of the representation of relief.) (Chapter XVI.)

12. Describe how you would make a closed traverse of a path bordering the whole of the park referred to in Question 11. Say how you would adjust any errors apparent when the field-book entries were plotted. (Chapter XVI.)

13. Guided by the following data, describe how you would map the relief of the park referred to in Question 11. Except that in the N.E. corner there is a circular knoll of about 40 yd. diameter and some 65 ft. above the general level of the park, the latter has no prominent relief features. Some trigonometrical heights are available, namely 268 ft. the highest point of the knoll, 205 ft. near the N.W., 173 ft. near the S.W., and 185 ft. near the S.E. corner of the part in which there is a broadly uniform slope from N. to S. In the lower half of its course the stream is artificially embanked some 4 ft. above the surrounding level. (Chapter XVII.)

14. Explain, with sketches, how you would measure the altitude of a small and conveniently accessible ridge from 300 to 500 ft. above a known height on surrounding land of generally uniform level. The ridge stretches from E. to W., its steepest side, a regular scarp-line, being on the south, and the northern side being broken by the head waters of two northward-flowing streams. (Chapter XVII.)

15. Describe, with sketches, the contouring of a sand dune about 60 ft. above mean sea-level, with the steepest side on the seaward face and the landward side fretted by minor re-entrants, the dune being relatively permanent and covered with binding vegetation. (Chapter XVII.)

16. Describe, with sketches, the contouring of an elliptical knoll, whose highest point is 80 ft. above the known initial level, and whose major and minor axes are respectively 100 and 60 yd. (Chapter XVII.)

17. Describe, with sketches, the contouring of a series of four river terraces which rise from the flood-plain of a rather wide meandering river, the highest terrace being 40 ft. above the general level of the flood-plain. (Chapter XVII.)

18. Explain, with approximate contoured sketches, how, given a topographical map such as the British 1-in. Ordnance Map, or the French 1 : 50,000 map, you would set about determining the intervisibility of pairs of selected points on the map. (Chapter XVII. and Chapter V.)

19. Describe the principle of the aneroid barometer, and explain under what circumstances, and how, you would use it to ascertain height of land in a newly explored country. (Chapter XVII.)

20. Since the preparation of the last edition of a certain sheet of the Ordnance Survey Six-inch Map, a considerable area of what was once agricultural and market-gardening land has been devoted to town-planning on "garden suburb" lines. How would you bring the map up-to-date to show the new houses and streets, and what instruments would you require? Give reasons for choice of such instruments. (Chapters XV. and XVI.)

21. Describe the work you would do with prismatic compass, Gunter's chain, and clinometer during a few days' traverse of field boundaries and roads in a lowland such as the Fen country. Illustrate by specimens of field-book entries. (Chapters XVI. and XVII.)

22. Plot the above field-book entries and say how you would adjust any possible errors. (Chapter XVI.)

23. If the work indicated in Question 21 was done around villages of the Lincolnshire or Yorkshire Wolds, how would it differ from that undertaken in the Fenland? Give specimen field-book entries and plot them. (Chapters XVI. and XVII.)

24. Describe how you would prepare the plan of a small village, with village green and with dwellings grouped around cross-roads. Give reasons for choice of instruments you would use, and illustrate by rough sketch of what the plan might be like. (Chapters XV. and XVI.)

25. How does the exploratory survey for an explorer's route map differ from that of good topographical survey? Suggest suitable instruments for an exploring party whose time is limited and whose facilities for transport are not good, supposing they are engaged in the survey of a tropical island such as New Guinea.

26. Give illustrative sketches to show the type of work which might result from methods noted in the preceding question.

27. What methods would you adopt and what instruments would you use in a property survey to check the plans of an estate. How and why does such a survey differ from topographical surveying?

28. It is desired to install telegraph lines through a belt of undeveloped country some 60 ml. long by 20 broad, lines being required for both longitudinal and transverse directions. A range of wooded hills, whose highest points exceed 2,000 ft., extends through the centre of the longest part of the region, the remainder of which is open grassland. Describe a simple method of survey which will produce a map sufficiently accurate for use of the telegraph engineers, and give reasons for choice of the instruments you would suggest. (Chapters XV.-XVII.)

29. Draw a sketch to represent a map which might result from such a survey, and note its limitations.

30. Describe how you would set about a rough determination of the relative heights of the salient features in an unexplored area of contrasted relief. (Chapter XVII.)

31. B and C are points known on the ground and approximately S.W. and S.E. of another known point, A. If these three points have been plotted on a plane-table, and if their heights are known, explain (1) how a point roughly S. of A, S.E. of B., S.W. of C. can be plotted on the plane-table; (2) how the height of this point can be ascertained. (Chapters XV. and XVII.)

32. Describe how to set up a transit theodolite over an indicated station, Y, so as to read the angle XYZ between two other stations X and Z, both "face right" and "face left." Show how you would record entries in the angle-book. (Chapter XIV.)

33. Describe how to make, on a scale of 1 : 15,840, a contoured map of about 4 sq. ml. of upland of the "Downs" type, if three well-distributed trigonometrical stations visible from all parts of the region are plotted on your paper and if their levels have been ascertained during triangulation. You are allowed the use of Plane-table and Indian clinometer and must fix your additional stations by resection. (Chapters XV. and XVII.)

General Questions (*Mainly on Part I.*)

1. Draw contoured sketches to show a cirque, a drumlin area, a basin of inland drainage in an arid climate, and add brief notes to explain their typical features.

2. Draw contoured sketches to show the difference between the drainage of a chalk plateau of fairly uniform height and that of a clay vale adjacent to the plateau scarp. Add brief explanatory notes.

3. Draw contoured sketches to show the characteristics of a fjord coast and of the adjacent country, where there may be ribbon lakes which further sinking of the land would transform into fjords. Mark the sites of possible settlements and give reasons for the same.

4. Draw contoured sketches to show the sites of probable human settlements—

(i) around an estuary which cuts through a range of chalk hills, but which is mostly surrounded by lowland.

(ii) in chalk uplands, the scarp side of which is fretted by the headwaters of small streams, there being several well-developed valleys on the gentler anti-scarp slope.

5. Draw contoured sketches to show the relief features and drainage of a formerly glaciated area and add brief explanatory notes where desirable.

6. Write a short essay describing and criticising the methods of showing relief on (i) topographical, (ii) atlas maps. Refer to concrete examples when possible.

7. To what extent is the practical surveyor concerned in the representation of relief referred to in the last question? What instruments would he probably use and for what specific purpose?

8. What is meant by the cartographical characteristics of a map? Illustrate by reference to the latest edition of the English 1 : 63,360, or the French 1 : 50,000 Official maps.

9. Similarly treat the International 1 : 1 million map.

10. Compare, from the standpoint of cartographical methods employed and the practical usefulness of such methods, the "Tourist" maps and the ordinary Popular Edition sheets of the one-inch O.S. map.

11. Compare the cartographical methods used on the one-inch map (Relief Edition) and six-inch O.S. plan.

12. What do you understand by "hydrographical" features? Illustrate by reference to any topographical maps contained in this book, and briefly describe such features.

HINTS FOR FURTHER READING AND STUDY

Candidates for the degree examinations of London University and others requiring more advanced preparation, are referred to the following books:—

Map Work, by V. S. Bryant and T. H. Hughes. A good general treatment of the practical methods necessary in map making, with hints for map reading and military sketching.

Maps and Survey, by A. R. Hinks. A standard and scholarly, but not too difficult, treatment of the study of Maps and the processes of Survey by which they are made. A very helpful book, especially when used in conjunction with some representative sheets of the various British and foreign Official Maps referred to in the chapters on map analysis.

Maps: Topographical and Statistical, by T. W. Birch. Treats the history, construction, and use of maps in a detailed, scholarly, and practical outlook. As the Preface says, "The object of the first part of this book, which includes information about maps past and present, land and air-photo survey, and map projection, is to contribute to an understanding of topographical maps, map-reading, and the interpretation of landscape as recorded on maps. The second part of the book deals with statistical maps and diagrams, and particularly with the problems involved in their preparation." A good advanced textbook and work of reference. The Bibliography is practical and comprehensive.

The Official *Text Book of Topographical and Geographical Surveying*, by Sir Charles Arden Close and Brigadier H. S. L. Winterbotham. The standard work of its kind. Surveying methods required for the production of large-scale topographical maps are described in considerable detail. Throughout, there is careful correlation between surveying and the map. Much useful information is given about projections and maps. An indispensable reference book for more advanced students.

Mathematical Geography, 2 volumes, by A. H. Jameson and M. T. M. Ormsby. Vol. I. deals with Elementary Surveying and Map Projections; Vol. II. with Simple Astronomical and Trigonometric Surveying, and the more advanced study of Map Projections. Founded on lecture notes of courses given to Internal Students of London University, these volumes are very helpful and very practical.

Land Forms and Life, by C. C. Carter. Largely an analysis of typical one-inch British Ordnance Survey Maps and a few similar foreign maps. In each case the physical features are examined in sufficient detail to explain settlement and other aspects of human geography. Very useful for the interpretation of topographical maps. It is desirable to use as many as possible of the typical map sheets referred to in the book.

Ordnance Survey Maps; their Meaning and Use, by M. I. Newbigin. Brings out the physical characteristics of typical regions like the Western Grampians, and is characterised by sound geographical scholarship.

The Geographical Interpretation of Topographical Maps, by A. Garnett. A useful help to map reading, especially in correlating such maps with human geography.

The Map of England, by Sir Charles Close. Contains much useful practical information about Ordnance Maps and is very helpful in map reading.

Map Making, by Professor F. Debenham. Very useful for surveying methods. Contains statistical results of various types of survey; deals with their entry, use, and, if necessary, their adjustment. Contains a very useful chapter on the making and adaptation of simple instruments.

Exercises in Cartography, by Professor F. Debenham. Practical work as done by first year students in the Department of Geography, Cambridge University. The actual exercises are accompanied by clearly-written chapters on various aspects of cartography. The chapters on Relief Models and Block Diagrams are particularly interesting apart from their academic value.

Key to Maps, by Brigadier H. S. L. Winterbotham. Explains the characteristics and used of many types of map. Contains much useful information about Ordnance maps.

The Weather Map, a standard Meteorological Office publication. Indispensable for understanding all about the preparation and interpretation of weather maps. The *Daily Weather Reports* of the Meteorological Office should be carefully studied and comparisons of typical weather maps made as these are issued.

Meteorology for Aviators, by Dr. R. C. Sutcliffe, and *Weather Study*, by Professor David Brunt, deal with the most recent methods of weather study and forecasting.

Map Projections, by A. R. Hinks. A standard textbook written by a geographer for geographers. It is indispensable for advanced students.

An Introduction to the Study of Map Projections, by Professor J. A. Steers. Endeavours to minimise the mathematical difficulties associated by some students with Map Projections. Is very good for graphical methods requiring a minimum of mathematics. This lucid and inspiring book can be strongly recommended.

Introduction to the Mathematics of Map Projections, by R. K. Mellish. Deals with the mathematical aspect of the subject and will be of interest to advanced students.

Geological Maps; *their Interpretation and Use*, by A. R. Dwerryhouse.

Geological Maps; *the Determination of Structural Detail*, by R. M. Chalmers.

The Study of Geological Maps, by G. E. Elles.

The first two books deal with the interpretation of geological maps, largely with a view to understanding the preparation of geological sections. The third stresses the interpretation of geological maps in relation to topographical maps. Whatever book is used, there is need for careful study of typical geological maps.

The Elements of Field Geology, by G. W. Himus and G. S. Sweeting. A very useful book which will enable the student to make a practical geological examination of a given area. Clear and practical diagrams are a feature of this book.

Stanford's Geological Atlas of Great Britain and Ireland. Very useful for its maps and for the wealth of explanatory detail.

O.S. Agricultural Atlas of England and Wales. Many distributional maps constructed according to the dot method and based on county statistics.

APPENDIX

REGIONAL SURVEY

For University Diplomas and Degrees in Geography, regional description of a selected area is usually required. Such description must be primarily based on personal contact with the region, and the necessary field work will be simplified by practical methods resulting in maps and diagrams not otherwise available.

The keynote of such a survey may well be " the physical basis and the human response," that is, how the physical geography explains human activity in work and settlement.

Begin by studying the relevant one-inch Ordnance map as recommended in Chapter VII., Arts. 1 and 2, and make the tracings suggested. Superimpose the tracing of (1) contours on that of (2) water features, *i.e.* streams, canals, lakes, and you will obtain a general idea of the distribution and character of physical features. Also, make tracings of the corresponding one-inch Geological Survey maps of the region. These, if used with the contours tracing, will help to explain the relief and soils. Note Chapter XVIII., Art. 5: " General Geographical Features of Certain Rocks."

You should now be prepared to examine the region " in the field," (1) at first to obtain a bird's-eye view of the actual country, and (2) later to concentrate on special features in more detail. In this practical study of the physical geography, ability to make perspective sketches and block diagrams, and to use a camera with a geographical eye will be useful. The geographical eye can pick out prominent features readily and adjust the camera to produce pictures with the best three-dimensional effect, *e.g.* from a vantage point on higher ground to obtain pictures of a meandering stream on the neighbouring plain, so that the meanders, levées, and possibly river terraces are clearly visible. For stream features note Chapter IV., Art. 4.

A block diagram is drawn on a block which is tilted to produce perspective effect. If (1) one end of the block faces the observer, as in Fig. 164, what is known as one-point perspective results when two sides of the block surface meet at a point on the horizon; (2) one corner faces the observer and two edges incline away from him, as in Fig. 165, the result is two-point perspective. A fully

developed block diagram shows geological structure beneath the topographical features, as in Fig. 168.

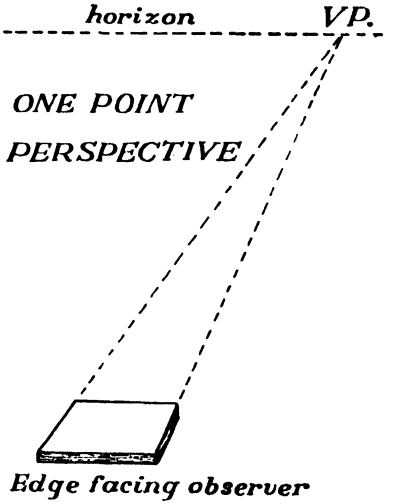


Fig. 164.

Perspective has a receding effect, so that (1) parallel lines, *e.g.* of a railway, receding from the sketcher, are drawn as though they converged to a point some distance from him; (2) a series of objects of equal size receding from the sketcher must be drawn as if they become progressively smaller and closer together, though they may really be the same distance apart, *e.g.* telegraph poles along a railway.

A simple way to make a block diagram from a map is to use the contours and (1) from them to construct sufficient profile sections along parallel lines on the map; and (2) to arrange on the contoured map these profile sections to give the three-dimensional idea; and (3) to use the sections as guides to a perspective sketch. This method, with others, is described by Professor F. Debenham in his *Exercises in Cartography*.

Block diagrams are useful for features such as a river valley, an escarpment or a ridge, provided there is not too much exaggeration of the vertical scale. Figs. 166 and 167 are based on photos taken by the writer, and represent valleys of streams rising in the Lincolnshire Wolds. Block diagrams of a wider area are generally reasonably successful if only the major features are shown and a minimum of shading is used, as in Fig. 168, which

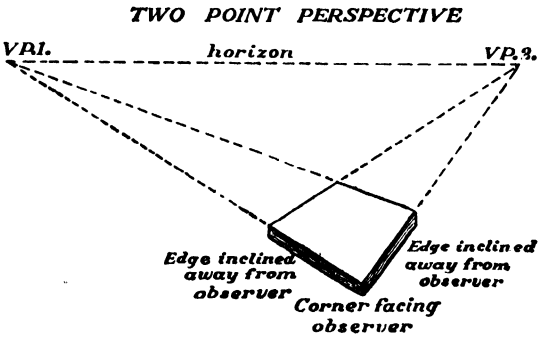


Fig. 165.

represents part of S.E. England, and is reproduced from Preece and Wood's *British Isles* (Univ. Tut. Press) by courtesy of the writers and publishers.

Practical exercises with surveying instruments required by examination syllabuses as " work in the field," might be done in suitable parts of the region, *e.g.* (1) route traverse of a stream or road, closed traverse of a park or common; (2) contouring of hill features or undulating ground; (3) theodolite triangulation of open, level ground, in which (4) details could be filled in by plane-tabling.

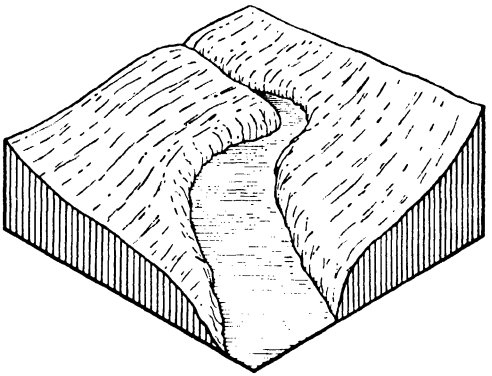


Fig. 166.

All work done " in the field," sketches, block diagrams, photos, results of surveying, should be dated. Notes of observations should also be dated, *e.g.* character of a stream valley and features observed therein, such as meanders, rapids, flood-plain. Sometimes it is helpful to make notes *on* a sketch map or diagram as it is drawn. They should be brief, and deal with outstanding points, such as type of soil or vegetation noticed when making a stream traverse, occurrence of springs at base of an escarpment.

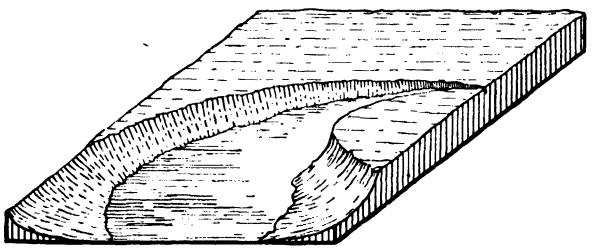


Fig. 167.

The human geography will be primarily concerned with occupations, communications, and settlement of to-day, though comparison with former conditions may sometimes be desirable. You can start by considering land utilisation: (1) productive (farms) or of relatively little value (moorland); (2) whether the farms concentrate on stock-rearing or crop-production or market-gardening, etc.; (3) mining; (4) industrial activity. Location of such enterprises can be

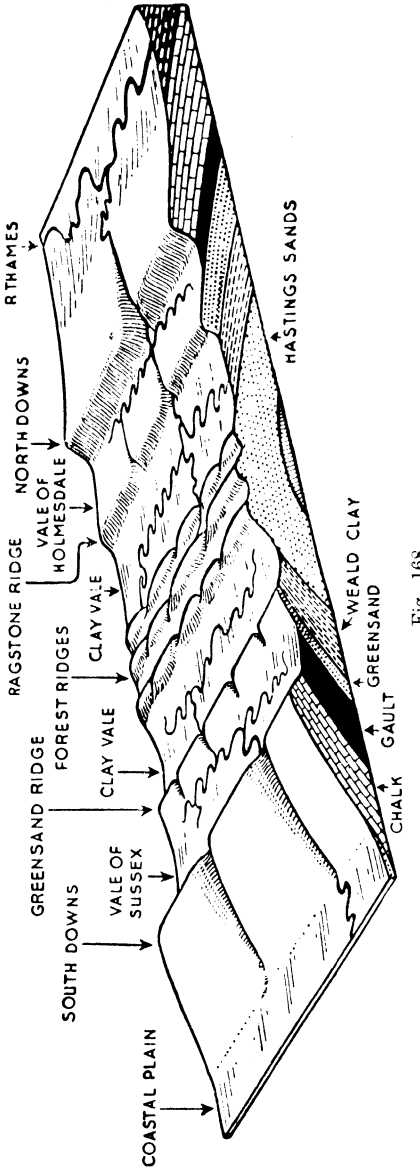


Fig. 168.

shown on a sketch map based on the one-inch O.S. Land Utilisation map, but some detailed study of agriculture will be necessary as regards distribution, products, methods.

The books entitled *Land of Britain*, edited by Dr. Dudley Stamp and generally issued for administrative counties covered by the Land Utilisation maps, contain useful information about agriculture and other economic exploitation of the land. Some of them have summaries about types of farms, and these you can extend by further examples from your own observation. If statistics are available, construct distributional maps for various crops and types of stock. (See Chapter VIII., Arts. 2 and 3). Generally, if sufficient reason be shown, the Ministry of Agriculture will furnish statistics relating to parishes or groups of parishes. You can attempt a small agricultural survey of your own, using the six-inch O.S. maps on which field boundaries are shown, and making enquiries of farmers, who, as a rule, will doubtless co-operate if they know your object. Some assistance can be obtained from the *O.S. Agricultural Atlas of England and Wales*, where, however, the area units are counties.

The communications tracing will help to explain many settlement sites (Chapter VI., Art. 7), and a separate settlement tracing can be made. Examination of village and town sites affords many interesting opportunities for work in the

field relative to soils, building sites, water supply, etc., and notes made should be dated, as conditions may vary according to season. Climatic statistics, if available, may be used to construct rainfall and temperature graphs, wind roses, etc., and these, if considered from the seasonal aspect, may assist your investigations into the incidence and reliability of water supply, type of farming, and other factors which have influenced settlement and land utilisation.

The above hints mainly concern practical work in the field, but for a dissertation reference to books and papers will also be necessary. A bibliography of these and of official maps, etc., should be compiled.

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