MAPS AND DIAGRAMS

MAPS AND DIAGRAMS

THEIR COMPILATION AND CONSTRUCTION

BY

F. J. MONKHOUSE

Professor of Geography in the University of Southampton

AND

H. R. WILKINSON

Professor of Geography in the University of Hull

*

WITH 199 ILLUSTRATIONS

LONDON: METHUEN & CO. LTD.
NEW YORK: E. P. DUTTON & CO. INC.

First published October 30th 1952
Reprinted with minor corrections, 1956
Reprinted 1958

1·3
CATALOGUE NO. 4256/U (METHUEN)

PRINTED AND BOUND IN GREAT BRITAIN BY
THE CAMELOT PRESS LTD., LONDON
AND SOUTHAMPTON

PREFACE

"Maps are drawn by men and not turned out automatically by machines," wrote the eminent American geographer, J. K. Wright, in his delightful essay 'Map Makers are Human'.[1] But proficiency in the art of drawing maps is not attained without some systematic training. The discipline necessary to attain this proficiency involves three things: (1) the handling of raw material and data; (2) a critical knowledge of cartographical principles and techniques; and (3) actual drawing practice to attain some degree of manual dexterity and skill in the execution of maps.

Problems concerned with the methodology of the compilation of data and with experiment in the technique of presentation constitute vital aspects of cartography; emphasis on these has perhaps figured less prominently in text-books than, for example, on the history of cartography, on practical surveying, and on map projections. The scope of cartography is so vast that no apology is needed for a selective approach, which omits consideration of these other aspects.

The map is the traditional medium of the geographer, and it is with the training of geographers that this book is primarily concerned. It must not be overlooked, however, that its contents should prove useful to the historian, to the economist and in fact to all who may have reason to handle or produce maps.

The maps and diagrams which a geographer is required to produce in the course of his training and development may be classified into three groups. The first group comprises those maps drawn as a series of formal cartographical exercises, to provide a course complete in itself, but naturally closely linked with the content of a particular geography syllabus, whether at school, training-college or university. At Liverpool, for example, all first-year students work through a systematic series of twenty-six exercises, with the object of replacing the extremely varied standards of school cartography by some general level of attainment.

The second group involves those maps drawn to illustrate the more or less elaborate dissertations and theses which form so important a part of more advanced work in training-colleges and universities. Frequently the dissertation comprises some type of regional survey, and the maps produced to illustrate it are of great importance. In fact, in some universities the dissertation presented for the first degree consists basically of a set of original maps, with a brief explanatory text.

The third group comprises maps which are drawn to be reproduced by line-blocks for publication. Many hundreds of books and periodicals

[1] J. K. Wright, *Geographical Review*, vol. 32, p. 527 (New York, 1942).

containing maps are published every year. All too often the maps they contain are poorly drawn, with inadequate lettering, either over-reduced so that legibility has suffered or under-reduced so that they are crude and empty in appearance, and frequently with heavy obliterating stipples. As V. C. Finch wrote, "A survey of geographic publications shows all too clearly how ill-adapted many of the maps and diagrammatic devices employed are to the purposes for which they were intended, and how often only a few minor changes would have improved their effectiveness had the author been more familiar with the range of devices and techniques at his disposal."[1]

The book has been divided into six chapters. The first is devoted to a preliminary discussion of materials and techniques, while the remaining five chapters deal with specific maps and diagrams which fall within the purview and scope of the geographer's interest.

The phrase 'maps and diagrams' has been interpreted in the broadest possible sense, for geographical data lend themselves to many possibilities and varieties of cartographical and diagrammatic treatment. In addition to the accepted concept of a map—a conventionalized depiction of spatial distributions viewed vertically—a wide range of diagrams has been discussed, including graphs, block-diagrams, profiles and landscape sketches. After all, a gradual transition can be traced from a straightforward topographical map, through various degrees of conventionalization and selective emphasis, to a simple diagram.

An attempt has been made to increase the value of this book by the inclusion of references to source material and data for map compilation, and to original articles, both those discussing the principles of some particular cartographical method, and also those illustrating the successful application of the various techniques. Bibliographical references are quoted fully in footnotes or in captions to maps and diagrams.

ACKNOWLEDGEMENTS

THIS book substantially embodies the cartography courses which have developed during the last five years in the Department of Geography in the University of Liverpool. Many of the exercises discussed have, in fact, been carried out in the departmental studios, and a large proportion of the illustrations in this book is derived from such exercises. In addition, invaluable experience has been gained in the drawing of the numerous maps contained in the several volumes of the Liverpool Studies in Geography, either already published by the University Press, or in the course of preparation.

We therefore owe more than we can adequately express, first to

[1] V. C. Finch, 'Training for Research in Economic Geography', *Annals of the Association of American Geographers*, vol. 34, p. 207 (Lancaster, Pa., 1944).

Professor H. C. Darby, and then to Professor Wilfred Smith for constant encouragement, stimulus and criticism, while our other colleagues have throughout contributed suggestions and advice, as well as a number of original maps.

Professor S. H. Beaver was kind enough to read through the proofs, and to suggest several amendments which we were glad to incorporate.

The most valuable part of a book of this nature is the maps and diagrams which illustrate it; these have been drawn by Mr. A. G. Hodgkiss, with the assistance of Mr. D. H. Birch.

F. J. M.
H. R. W.

Liverpool
June, 1951

CONTENTS

ILLUSTRATIONS

CHAPTER I

MATERIALS AND TECHNIQUES

Drawing Instruments

It is essential for a student who desires to acquire a reasonable cartographical technique to provide himself with an efficient set of drawing instruments, and to learn their use by systematic practice.

Pencils

Much preliminary work is necessarily carried out in pencil. A hexagonal pencil is better than a circular one, as it prevents rolling or slipping. Leads are made of graphite compounds of varying degrees of hardness; thus 8H or 9H leads are of metallic hardness and will scratch or cut the surface of the paper, while a 6B lead is extremely soft. For most drafting work, either an HB or an H pencil is adequate. A 6B or a solid carbon pencil may occasionally be used for such operations as hill-shading, but such a map should be protected from smudging with an overlay of tracing- or tissue-paper.

A pencil point must be kept really sharp. A mechanical sharpener is useless, and the lead should be sharpened with a keen knife and brought to a needle-point by rubbing it on a sand-paper block. For ruling lines against a straight-edge, sharpen the pencil to a chisel point.

Pens

Many types of nib of specialized design are on the market; most of these are chiefly of value to professional draughtsmen. A broad medium-sized stiff steel nib, one or two double-pointed nibs which will draw parallel lines (for roads and railways), and a ball-pointed nib for dotting and stippling, will all be useful to the student. A mapping-pen can be used for fine line-work, but it is essential that perfectly even pressure should be applied on up-and-down strokes, for one of the main difficulties in its use is the varying line thicknesses produced. It can be employed for rivers, where a tapering line is required.

The main problem of the ordinary cartographer is to obtain a uniform thickness of line. One solution is to use a pen such as the *Uno*, which consists essentially of a series of detachable cylinders of varying diameter, numbered from 0 to 7, each of which produces a different line thickness (Fig. 1), and is supplied with ink from an attached conical reservoir. Each nib fits a wooden or plastic holder. A certain amount of care with a *Uno* is necessary to maintain an even flow of

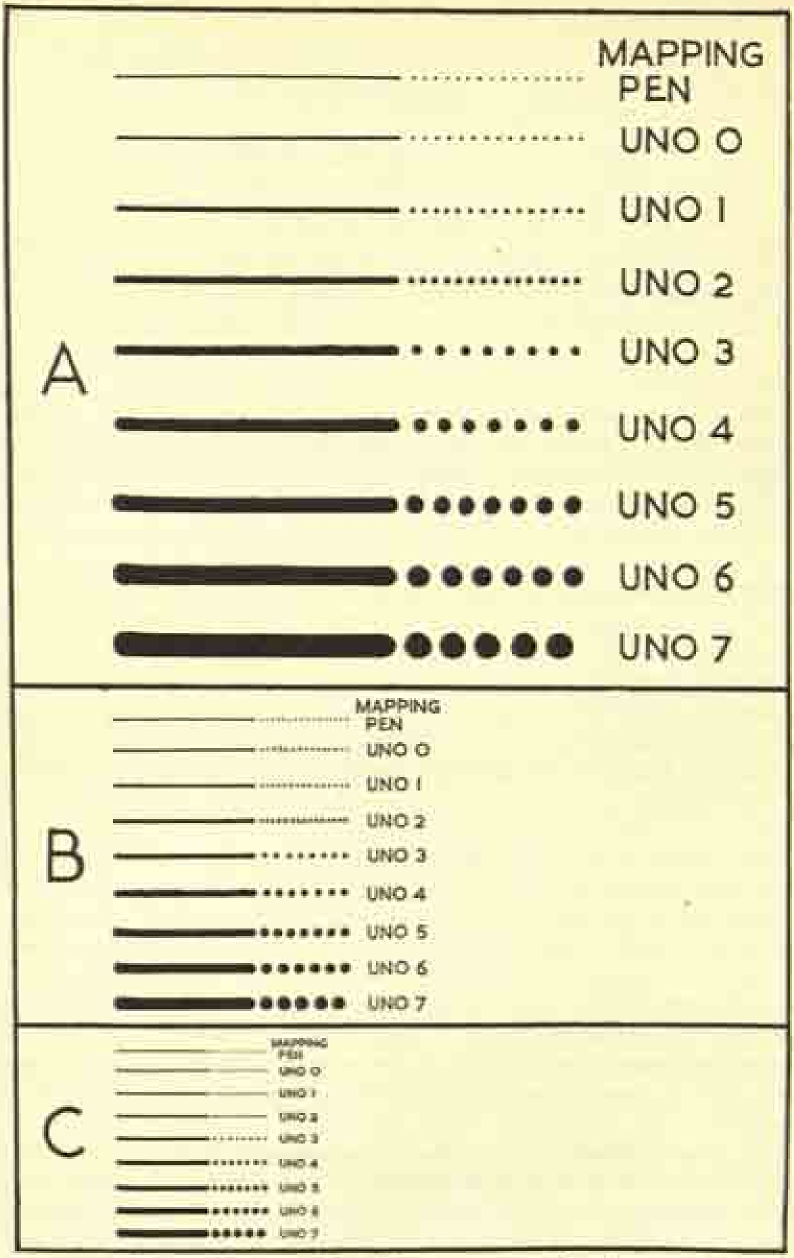


Fig. 1. Standard Line Thicknesses and Dot Sizes

Nine standard thicknesses of line and sizes of dot, obtained by using a mapping-pen and eight *Uno* grades, are shown: **A.** full size; **B.** reduced to one-half; **C.** reduced to one-third.

ink. The pen must be held vertically. It must be kept absolutely clean, and every time the ink in the reservoir is exhausted it should be dipped in hot water, the wire in the cylinder carefully pulled up and down, and the cylinder wiped off with a piece of fluffless material.

Ruling-Pens. A ruling-pen consists of a handle with two blades each tapering to a point, the distance apart of which can be regulated by a screw; some types have a hinged nib, which allows for easier cleaning. The blades should be kept sharpened on an oil-stone. The pen must not be dipped in ink, for any ink on the outside of the blades will produce blurring; the ink is inserted between the blades by a quill or by an ordinary pen or brush, or from a tube. The student must experiment with the various settings of the screw and the resulting line-thicknesses, and it is advisable to rule a few trial lines before starting on the map itself.

Ruling-pens which rotate on their handles, and so can be used to draw curving lines, are available, but are not of any great value to the cartographer. Double ruling-pens, which consist of two ruling-pens fastened in a single holder, adjustable so that double lines can be ruled of varying thickness and distance apart, are sometimes of convenience for inserting railway-lines, roads and canals (Fig. 2).

Ruling-pens need considerable practice. They should be held lightly in a vertical position against a straight-edge, preferably of steel, and bevelled to prevent the ink-lines from running; this edge must not be so high that the line wavers. The pen must not be so full that the line is blobbed, nor so dry that fine double lines are produced instead of a single line of correct thickness. However, when the technique is mastered, it enables clean-cut lines to be ruled, and it is of great value for line-shading (see p. 37). Where a thick marginal line is required, it is better to rule two parallel lines and then fill in the intervening space with a fine brush.

Quill-pens may be used, with practice, for lettering. "No one who has learned to cut a quill will ever again be content with a steel pen. . . ."[1] Either a goose or turkey quill is used; the former are more supple and wear longer, while the latter are much stiffer. For very fine work a duck or crow quill may be used, while for large work, such as wall-maps, a reed or cane is employed. The quill has to be cut cleanly with a very sharp knife to the desired shape of nib; much practice and experiment is necessary to do this successfully and to find a shape which suits the individual draughtsman. Ink should be put into the quill with a filler. The great advantage of quill-pens is that lettering is speedy; only a single stroke is needed, for gradations of thickness are easily produced by different pressures, and 'building-up' is unnecessary (see p. 45).

[1] G. Hewitt, *Lettering*, p. 251 (London, n.d.).

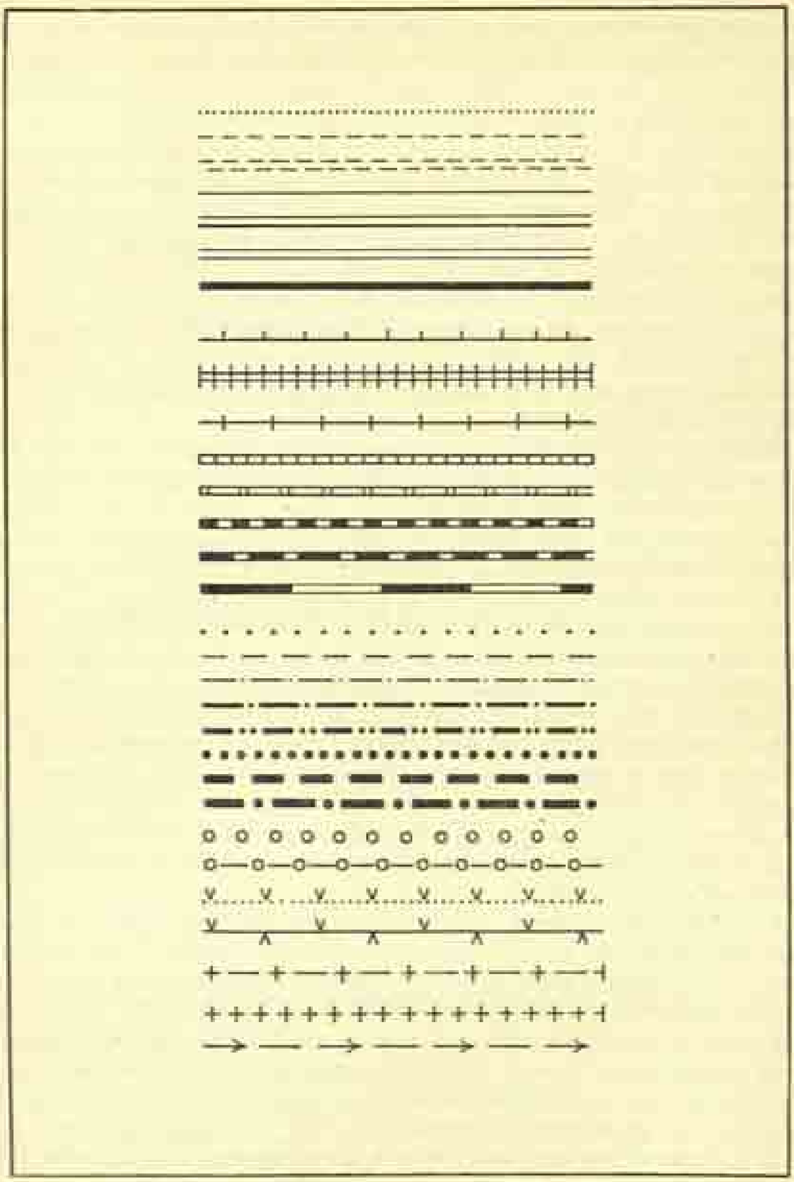


Fig. 2. Varieties of Line

Various distinctive lines are used for categories of footpath, roads, railways, waterways, political boundaries, electricity grid cables and aqueducts.

The Fountain-Pen Drawing Instrument. A continental drawing instrument, known as the *Graphos,* has been recently introduced to this country, and may well prove to be a great boon, particularly to the student-draughtsman. It consists of a holder containing an ink-feed, which is filled by means of a pipette from an ink cartridge. A feed-duct, protected by a metal cylinder, projects from the holder; it is slotted to take the tongue of a nib, which can be easily slid into position. A wide variety of hard steel nibs is available, including fine and broad ruling nibs, tubular nibs for stencil-lettering, slant nibs for square-ended lines, round nibs for round-ended lines, and a fine drawing-nib for free-hand work. This single instrument will enable a draughtsman to carry out virtually every form of line-work and lettering with no more trouble than changing a nib.

Other Instruments

A variety of other drawing and geometrical instruments will at times be found useful. Minimum requirements comprise a pair of compasses (preferably fitted with both pencil and ruling-pen), dividers, a large celluloid set-square with bevel-edges for ink-work, a protractor, a hard-wood T-square for laying out margins, a steel straight-edge, hard-wood inch and centimetre scales, various celluloid curves or an adjustable flexible curve, and parallel rulers for setting out parallel lines or for line-shading.

The Drawing-Table

Drawing-paper can be rested upon a hard-surfaced drawing-board, tilted at a slight angle. More convenient, indeed essential for good line-work and for copying, is a drawing-table, the top of which consists of heavy glass, and can be illuminated from below. This will enable maps to be copied easily on tracing-paper, and it is possible, given a sufficiently brilliant illumination, to trace on to apparently opaque drawing-paper. Lead weights, covered with baize, are better than drawing-pins to keep the tracing from slipping over the original or first draft, or the tracing may be stuck down by strips of adhesive tape over each corner.

INKS AND COLOURS

Indian Ink

Indian ink consists of fine lamp-black suspended in a liquid medium. It is deep black, waterproof, and photographs well, but it dries very rapidly and the cartographer must keep his line-work moving. All cartographic work, whether for the exercise book, the dissertation, or for line-blocks, should be finished off in Indian ink, because of its clean, clear-cut effect. When exposed to the air the ink in a bottle

coagulates and dries out rapidly, and unless it is corked when not in use, the ink soon deteriorates; it is economical to fill a small bottle periodically from a larger one. It is preferable for *Uno* and ruling-pens to use ink supplied in plastic tubes, which on being squeezed at the base will exude from the nozzle the desired amount of ink of correct fluidity.

Water-Colours

Water-colours can help, if used with discretion, to clarify maps for the cartography note-book and for the dissertation. Ordinary water-colours, made in tubes and cakes, or aniline powder-dyes, may be employed. Several sable brushes, broad ones for washes and a few finer ones for detailed work, are needed. One brush should be kept for painting with Indian ink, where considerable areas have to be blackened, or double lines filled in. Another may be reserved for applying white paint to obliterate unnecessary lines on drawings for the block-maker, and a third for tinting with coloured waterproof inks. It is necessary to emphasize that brushes and paints should be kept scrupulously clean by washing them thoroughly in warm water after use.

Other Colours

Crayons and coloured pencils are occasionally useful to colour exercises, but the results are generally cruder than if water-colours are used. Coloured waterproof inks are helpful for line-work (as, for example, blue for rivers and red for railway-lines). Where the areas concerned are small these inks may be applied with a brush, but it is difficult to obtain a smooth wash with ink over a large surface.

Drawing Media

Note-Books and Folders

Where a student is working through a systematic series of exercises, it is obviously desirable that these should be arranged and presented in some permanent form. There are three alternatives: a bound note-book, a loose-leaf file, or a large envelope or folder. Each has its advantages.

A note-book should have stiff covers, well guarded at the binding to allow drawings to be pasted in, and interleaved with graph- and writing-paper. Written exercises, calculations, notes on methods, and various graphs and diagrams can be written or drawn straight in, while maps on drawing-paper may be carefully mounted with or without one or more guarded folds. A carefully compiled note-book, containing a series of exercises executed week by week, will constitute a most useful and attractive reference book of cartographical methods.

A loose-leaf file should have good stout covers and some efficient binding system; it allows the convenient storage of work of different dimensions on varying media, and is flexible in arrangement. Where the course consists of a few major exercises, a large stout envelope is probably most useful. Alternatively, the maps may be kept in a folder consisting of two sheets of cardboard hinged together by a strip of adhesive linen, with the open ends secured by tapes.

Drawing- and Tracing-Papers

Drawing-paper should be used for all finished map-work, except where it is to be reproduced (when tracing-paper is adequate). Ordinary cartridge-paper, or a matt-surfaced machine-pressed paper, or thin card such as Bristol board, may be used for particular jobs. Obviously the cheaper media will not stand much erasure, nor will they take smooth colour-washes.

Tracing-paper is made in a wide range of qualities; a good paper is tough, of a smooth matt surface with no gloss, and highly transparent. Maps for the block-maker can be drawn directly on to tracing-paper in Indian ink; copying by tracing, and any alterations and obliterations, can be more easily done than on card. Tracing-papers, however, expand very appreciably, particularly on damp days, and especial care must be taken with the exact register where drawings are intended for two-colour blocks. Tests show that a change of 40 per cent relative humidity may produce a distortion exceeding two per cent in either direction, which with a sheet a foot square may amount to a quarter of an inch. These papers tear easily, and tracings should have their edges guarded by adhesive tape of some kind; a small machine may be used to bind the edges with special linen tape.

Tracing-paper is also useful for overlays. For example, a tracing of geological outcrops may be superimposed on a topographical map to emphasize some significant relationship (see p. 108).

Various other media, such as vellum, cellophane, tracing-cloth, and drawing-paper mounted on linen or muslin, are used by professional draughtsmen for certain specialized work.

Plastic Media. Various plastic materials are now available for cartographical work. They have a high degree of dimensional stability, and are especially useful for colour overlays to ensure a high fidelity of register. Such a medium is *Kodatrace*, a grainless cellulose plastic material, finished matt on one side to take pencil, ink or colour, and tinted faint blue. It has a high degree of transparency, for it allows 74 per cent light transmission; it has an extremely smooth and uniform texture, yet is tough and flexible; it takes ink without cockling, even when large areas are blocked in; and it is impervious to water. It can be cleaned easily, using ammonia on cotton wool for removing

ink, or a soft rubber or a damp cloth for pencil. Another very attractive medium is the *Ethulon* tracing-film. Several varieties of plastic sheet are produced in America, such as *Vinylite*, *Copyrite* and *Dyrite*. One variety consists of a sheet of plastic laminated with paper on either side. These plastics are almost dimensionally stable.

Graph-Papers

It has been recommended that the cartography note-book be interleaved with arithmetic graph-paper, preferably ruled in inches and tenths of inches. This will enable a wide range of graphs to be drawn straight into the note-book. Sometimes a larger sheet may have to be mounted in the note-book with one, two or more folds.

Semi-logarithmic graph-paper, which combines a horizontal arithmetic scale-ruling with a vertical logarithmic scale-ruling, may be needed where it is desired to plot rates of change (see pp. 203, 273). This paper is available in a series of cycles, and can be scaled a desired in powers of 10. Thus with five-cycle paper, the lowest cycle may be 1 to 10, the second 10 to 100, the third 100 to 1,000, the fourth 1,000 to 10,000, and the fifth 10,000 to 100,000. Should larger numbers be needed, the lowest cycle might begin at 10,000 or 100,000. Sheets of two-way logarithmic paper (i.e. with both horizontal and vertical logarithmic scales) may occasionally be required for frequency graphs.

Circular graph-paper may prove very useful in drawing some projections, for wind-roses, and for diagrams showing seasonal distribution of climate and of human activity. *Percentage circular graph-paper*, in which the circle is divided into one hundred segments, facilitates accurate and speedy plotting of divided circles (see pp. 153, 189). *Triangular graph-paper* may be used when three variables have to be plotted, as for example, three related aspects of climate. Another type of graph-paper, *isometric*, enables three dimensional figures, such as block-diagrams (Fig. 44), to be constructed without recourse to angular measurement. *Arithmetical probability graph-paper* is invaluable for plotting probability curves as, for example, of rainfall (see p. 151).[1]

Map Compilation

General Features

Whether a map or diagram is drawn by a student as an exercise, or by an author to illustrate his monograph, it is essential in most cases to compile a preliminary draft. The cartographer has to consider the aim or purpose of his map, the source material from which it is to be constructed, and the most striking and effective method to

[1] A variety of graph-papers is illustrated in *The Chartwell List of Graph Data Sheets*, published by W. Heffer and Sons (Cambridge).

be used. He selects carefully his base-outline, the scale, and the size of the finished map or of the desired reduction. It often happens that a map, clear and attractive in its original form, is disappointing upon reduction; it may be under-reduced, so that it is crude and empty-looking, or (more frequently) over-reduced so that legibility has suffered. As V. C. Finch wrote, "The editorial staffs of the geographical periodicals know to their sorrow how many good-looking manuscript maps and diagrams present almost insoluble problems in printing owing to failure of the authors to grasp the elements of scale and proportion in drawing for reproduction."[1] While it is possible to standardize the size of lettering, line-thickness and density of shading suitable for any degree of reduction, it is often necessary to make an actual trial. A photographic reduction can be made, or when a large series of maps is contemplated it may even be well worth having a trial block made. It should be noted that the amount of reduction is expressed in linear terms, not areal, i.e. an original map of ten by five inches will, for a half reduction, appear as five by two and a half inches. The compiler must be careful, when concerned with an awkwardly shaped map, to mark the correct controlling dimension; thus an original map, 16 by 8·2 inches, marked for a reduction width of 4·1 inches, would be too long for a page which measures 7 by 4·1 inches. In this case, the length should be marked as 7 inches, even though the resulting block will be slightly narrow for the page. In general practice, a block should be made less than the actual page-size, in order to afford room for title and caption.[2]

The correct balance of the map is sometimes difficult to attain, especially when an awkwardly shaped or irregular area is involved. The most convenient positions are assigned to the key-panel, the scale-line and the cartouche (see p. 17). The compiler chooses in the light of his experience the correct line-thicknesses, stipples or line-shadings, and symbols, and the character and size of the lettering. Care has to be taken not to overload the map with detail which might obscure the main theme of the map.

As a rule, a first pencil draft should be carefully prepared, either to be inked in or to serve as a precise copy from which a finished tracing may be made. When a pencil draft is to be inked-in, rub the map lightly with a very soft 'soapy' eraser (such as '*Artgum*'), or with a powdered erasing medium, so that the pencil lines, while still visible, become as faint as possible, and dust the paper carefully. Indian ink should never be applied over heavy pencil lines, as the stability and

[1] V. C. Finch, 'Training for Research in Economic Geography', *Annals of the Association of American Geographers*, vol. 34, p. 207 (Lancaster, Pa., 1944).

[2] An interesting general article on this subject is by A. B. Clough, 'The Preparation of Maps and Illustrations for Geographical Articles and Theses', *Scottish Geographical Magazine*, vol. 60 (Edinburgh, 1934).

permanence of the inked lines is thereby impaired. It may be mentioned that when the map is being traced from a direct source, there is no gain in preparing a preliminary pencil tracing. This not only doubles the time taken, but increases the possibility of minor errors. Instead, using a lighted tracing-table, draw the map straight away in ink; the only pencil lines needed will be guide-lines for the lettering.

Base-Maps

A base-map is an outline map used for plotting information. It may consist of the coastline and frontier, or major or minor administrative divisions, contours, field-boundaries, or natural drainage patterns. These outlines may be extracted from topographical maps or from atlases, and occasionally they are provided by national Institutes of Geography and other organizations.[1]

Duplicated outlines can be issued to a class as a basis for a specific exercise, and can be used by a research worker who has to plot a number of distributions on the same base.

Map-Checking

All maps should be minutely checked upon completion. The compiler should where possible secure the help of one or more critics to whom the map is novel, for all too often he may miss the most obvious errors because of his familiarity with the map. The checking should be systematic; spelling, line-work, shading, key, scale-line, all must be checked in turn. The caption should be checked at the same time for correct title, source or acknowledgement, and explanatory comments.

Key-Maps

When a series of maps has been completed, either for a dissertation or a published monograph, the maps should be carefully numbered in order of first reference in the text, and a list of their titles included in the table of contents. A key-map, placed at either the beginning or end of the text, is often useful to locate the various maps. Thus a series of a dozen large-scale coast maps may be located on a small-scale map of the whole coast, each map being shown by a rectangle drawn to scale and numbered with the consecutive figure number. Similarly, a series of scattered village plans can be located on a map of the whole county. This is particularly helpful to the general reader when the monograph is of a detailed nature, and widely dispersed regional examples are used.

[1] For example, the *Institut National de la Statistique et des Etudes Economiques* (*Ministère de l'Economie National Paris*), published a base-map on a scale of 1 : 600,000, entitled *Régions Géographiques d'Economie National*. The map was specially prepared for use as a base-map for statistical plotting.

Scales and Scale-Lines

Definitions

Through usage the word 'scale' has come to be employed in two distinct senses. In the first place, it denotes the relationship which the distance between any two points on the map bears to the corresponding distance on the ground, expressed either in words, as 'one inch to one mile', or as a representative fraction (R.F.), as 1/63,360.

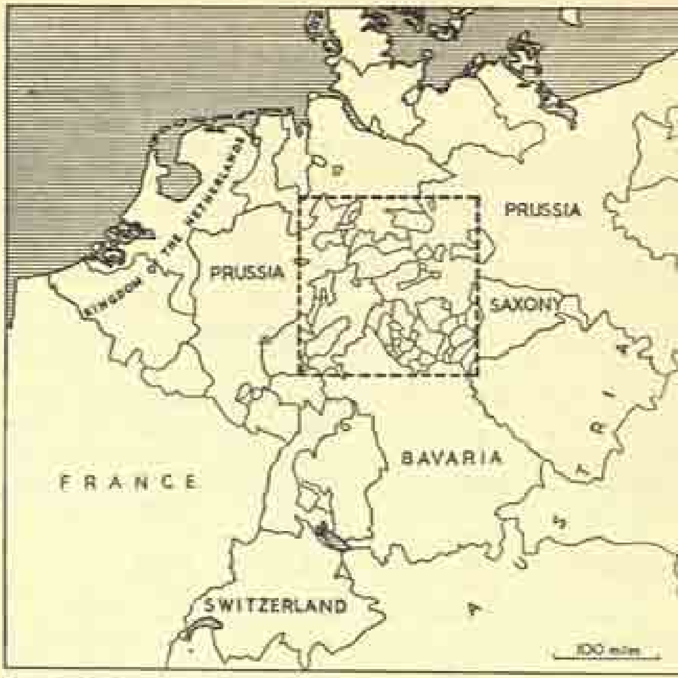
Useful R.F. Conversions

R.F. 1/to	*Miles to 1 inch*	*Inches to 1 mile*	*Km. to 1 cm.*	*Cm. to 1 km.*
Million	15·78	0·0634	10·0	0·1
633,600	10	0·1	6·336	0·1578
500,000	7·891	0·127	5·0	0·2
253,440	4·0	0·25	2·534	0·395
126,720	2·0	0·5	1·267	0·789
100,000	1·578	0·6336	1·0	1·0
63,360	1·0	1·0	0·6336	1·578
50,000	0·789	1·267	0·5	2·0
25,000	0·395	2·534	0·25	4·0
10,560	0·167	6·0	0·1056	9·468
10,000	0·158	6·336	0·1	10·0
2,500	0·0395	25·34	0·025	40·0
1,250	0·0198	50·69	0·0125	80·0

Used in the second sense, the word scale denotes a line-scale which enables distances on the map to be directly measured and read off in terms of distances on the ground. All maps should bear a line-scale.

When compiling a map, the first essential is to determine the scale to be used. It is obviously necessary to take into account the extent of ground to be depicted and the available size of the paper. The amount of detail which can be included is clearly a function of the scale, in that a large-scale map will show a smaller area in greater detail than a small-scale map. Thus Fig. 4 is an enlargement of one portion of Fig. 3, in an effort to clarify the complexity of the intricate pattern of state boundaries; the scale of the lower map is four times that of the upper.

A further complication is introduced if the original drawing is to be reduced, either photographically for a dissertation, or to make a


KINGDOM OF THE NETHERLANDS
PRUSSIA
PRUSSIA
SAXONY
BAVARIA
FRANCE
SWITZERLAND
100 miles


25 miles
HANOVER
BRUNSWICK
PRUSSIA
HANOVER
PRUSSIA
HESSE-CASSEL
HESSE-DARMSTADT
BAVARIA

line-block. In either case, the scale should be indicated on the face of the map as a line-scale, and not expressed in words or as an R.F.; the last two will obviously be invalid upon reduction. The line-scale is of course reduced in the same proportion as the map.

There are two types of line-scale. The first is the long accurately divided line, used for large maps, which enables direct measurements with dividers to be made. The second is the short, inconspicuous line drawn on a small map which gives merely a general idea of actual distances involved, but is unlikely to be used for more than a casual measurement by eye.

Long Line-Scales

The calculation and construction of a long line-scale, which should as a rule be about six inches in length, forms a useful cartographical exercise, and helps to drive home the principles involved. From experience, it is incredible how confused many students become when faced with an R.F. which they are requested to convert into a line-scale.

Suppose it is necessary to draw a line-scale, indicating miles, for a continental map of R.F. 1/50,000.

On the continental map, 1 *mile is represented by*

$$\frac{63{,}360}{50{,}000} = 1{\cdot}2672 \textit{ inches}$$

$\therefore$ 5 *miles is represented by a line of length*

$$1{\cdot}2672 \times 5 = 6{\cdot}34 \textit{ inches.}$$

Draw this line accurately, then divide it into five, by setting-off similar triangles. This is done by drawing any line five units in length, at a reasonable angle from the left end of the line-scale. Join the end of this line to the right end of the line-scale and rule lines parallel to this from the unit intersections on the upper line. This will give the divisions on the line-scale itself. It has been calculated that one mile on the ground would be represented by 1·2672 inches, and this distance can be stepped off five times with dividers. It is clear, however, that when a single line is drawn there is one possible error of measure-

---

FIGS. 3, 4. ENLARGEMENT OF SCALE

Based on a contemporary map, *The German Confederated States* (London, 1839).

The complex portion of the upper map demarcated by a pecked line is shown on the lower map on a scale four times as great. This enlargement enables some state-names to be inserted for reference.

ment, which by division into five is distributed; when the five small lengths are stepped off, the errors of measurement are cumulative and may be quite appreciable. The division on the extreme left of the line can be further divided into four or eight to show quarter-miles or furlongs; this is known as an open divided line-scale. If the whole line is divided, it is known as a fully-divided line-scale, but this is not usually necessary. When numbering the scale, zero should fall one interval along from the left, so that the left-hand end of the line will be numbered 1, and the divisions to the right of zero will be numbered 1, 2, 3 and 4. When measuring a length with dividers, place one leg on the nearest whole number on the right of zero, so that the fraction can be read off directly to the left of zero (Fig. 5, example A).

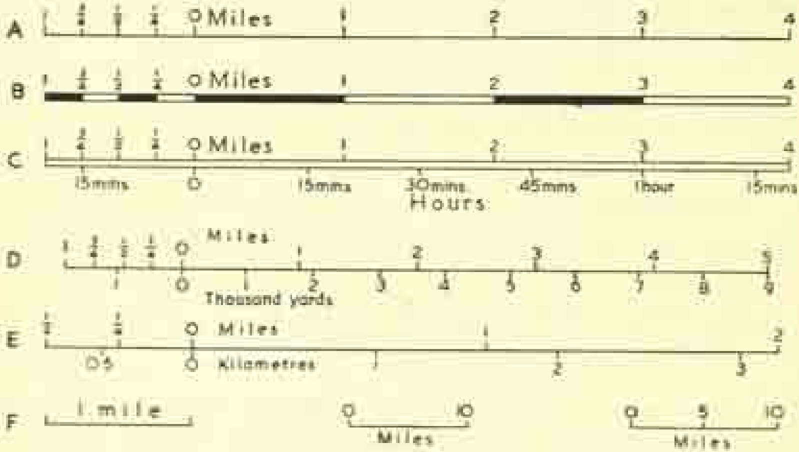


Fig. 5. Line-Scales

A. Open divided line-scale; **B.** filled line-scale; **C.** time and progress line-scale (the time-scale represents a uniform speed of 3 miles per hour); **D, E.** double linear-unit line-scales; **F.** short line-scales.

The line-scale should be drawn as a single clean line, marked with neat ticks of uniform height. Double lines, with alternate spaces filled black, are commonly used for effect, but should be avoided if exact measurements are desired, since the black sections are actually longer than the white by the thickness of the bounding line at either end (example B). A second scale can be placed on the underside of the line if necessary; it might be a uniform time and progress scale (example C), or a scale of different linear units, such as kilometres or thousands of yards below a mile scale (examples D, E).

Diagonal-Scales

It is occasionally necessary, particularly on large-scale plans, to be able to subdivide the first unit length with considerable precision, and a diagonal scale may then be used (Fig. 6). Suppose that it is necessary to draw a line-scale of R.F. 1/633,600 (i.e. 10 miles to 1 inch) to show miles and furlongs; direct division to represent a furlong on such a small scale would be out of the question, for it would be only 0·0125 inches in length.

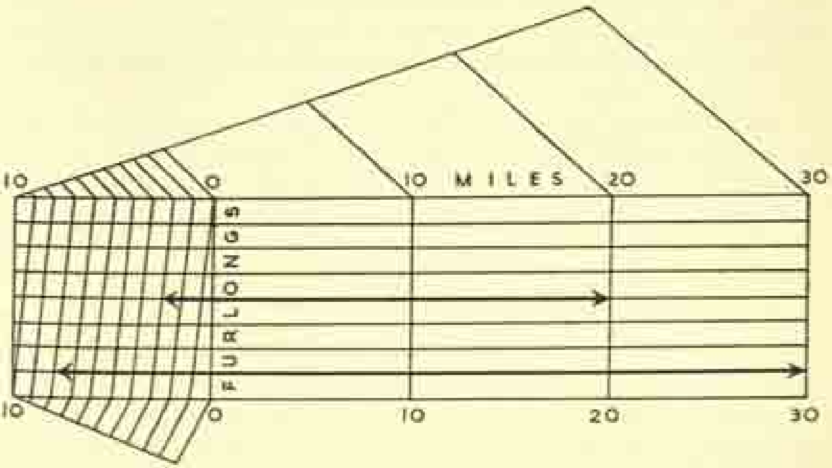


FIG. 6. A DIAGONAL SCALE

This shows miles and furlongs. The upper arrow indicates a length of 22 miles, 4 furlongs, the lower of 37 miles, 7 furlongs.

Draw a line 4 inches long, dividing it into four portions of 10 miles each by setting-off proportional triangles. The left-hand unit can be divided into ten parts to indicate mile lengths, but these will only be 0·1 inches long, and are obviously indivisible into eight further portions to represent furlongs. To obtain these furlong divisions, construct a diagonal scale, as shown in Fig. 6; here the distances represented by arrows marked are 22 miles, 4 furlongs and 37 miles, 7 furlongs respectively.

Short Line-Scales

These lines are used commonly on maps intended for reduction as line-blocks, and are indicative, rather than for use in precise measurement. They should be reasonably small; thus a line one inch in length is adequate for a map to be 4 inches wide on reduction, but if there is a large blank area in one corner it may look better to have a longer

line. Care must be taken to ensure that the vertical dividing ticks are sufficiently large to appear when reduced. Choose carefully where to place the line-scale; this is, of course, part of the general lay-out and compilation of the draft. Avoid if possible a corner with crowded detail; it may be necessary to cut out a narrow panel and inset the line, or to put it inside the key panel or below the title. Each map must be viewed on its own merits, and the scale placed where it interferes least with the detail. Various alternative forms of line may be used (Fig. 5, example F), but uniformity throughout a single series must be maintained. Consider carefully the style and size of the lettering and figures; O's especially are apt to look extremely ponderous.

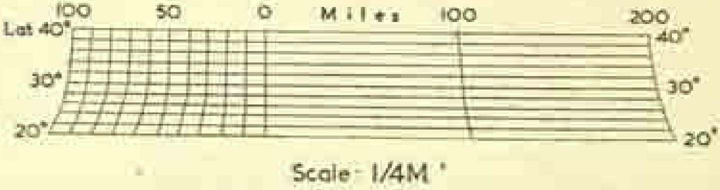


Fig. 7. A Variable Scale

This scale, constructed for a Conical Orthomorphic Projection, with two standard parallels at 27° and 63° North latitude, enables distances to be correctly measured along parallels between 20° and 40° N.

Other Scales

On small-scale maps of extensive areas, a scale may occasionally be omitted if a graticule is drawn, or if meridian and parallel intervals are indicated in the margin; in either case, the projection should be stated. Otherwise a *variable scale* (Fig. 7) should be used, or the average scale for the central portion of the map stated.

The easiest way of giving the scale of a block-diagram is to state in the caption the distance between two clearly identifiable points on the diagram. A *perspective scale*, which decreases from the foreground to a vanishing point on the horizon, can be used if required for a landscape drawing, but again a statement of the distance between two points is usually adequate. The *horizontal* and *vertical scales* are marked on the base and left edge of sections and profiles, while the vertical exaggeration should also be stated (see p. 69).

Using the word 'scale' in its broadest sense, it can also include diagrams which enable quantitative measurements to be read off; thus there are horizontal and vertical scales on line-graphs and columnar diagrams, scales which enable proportional squares, circles and spheres to be drawn or evaluated, and scales of slopes. Each is discussed below in its relevant place.

Frames and Panels

Margins

A map must have a margin or frame; detail, except on simply-drawn sketch-maps, must not be left 'hanging in mid-air', but must be continued to the margin. Graphs and diagrams may or may not have a frame, depending on their appearance. The margin, together with a panel for the key and, if needed, another for the title, should be ruled in as a preliminary to the inking-in of the pencil draft. The position of these panels depends on the lay-out of the detail on the map, and should be carefully considered during the preliminary compilation; usually they will be placed in empty corners, or centred on the bottom margin. Sometimes they may be conveniently placed where the detail is irrelevant to the main purpose of the map (Figs. 105–8).

Margins or frames should be as simple as possible. For a line-block, a single bounding line, cleanly ruled with sharp corners, is quite adequate. For larger manuscript maps, it is permissible to have an inner margin, with an outer one of a heavier line, or with a double line, either open or filled black and white in alternate spaces, possibly to show degrees or linear units. But elaborate scrolls, designs and ornamental corners should be strictly avoided.

Cartouches

This avoidance of elaboration applies also to the cartouche, a panel in which the title is placed if one is needed on the map. Elaborately decorated cartouches were the delight of the Dutch Renaissance cartographers and the Elizabethan county map makers, but they are usually out of place in a modern map (see Fig. 178). As a rule, the title need not appear on the face of a map intended for a line-block, but it can be set up below in type. On a large manuscript map, the carefully lettered title is, however, an integral feature.

Key-Panels

The key-panel should be carefully compiled so as to include a reference to all symbols, shading, stipples and special lines used on the map. Normally a frontier or coastline need not be keyed, but if different lines are selected for international, provincial and communal boundaries, they must be explained. All shading should be placed in small detached rectangles, which are clearer than divided columns. For relief map keys, put the darkest tint (highest land) at the top of the series; in geological maps put the stipple representing the youngest formation at the top. The key panel must be carefully laid-out to give a balanced appearance, economizing in space, maintaining a strict rectilinearity of arrangement, and using succinct definitions. A time- and space-saving idea is to number the items and list the numbers,

with their definitions, in the legend below (Fig. 129); much fuller explanations are of course possible than could be lettered on the map, and moreover this saves valuable drawing time. Sometimes it is preferable, where a key is particularly involved, and when it is essential for it to appear on the face of the map, to have the definitions set up in a carefully chosen fount of type. These are cut out and pasted on to the drawing in their correct position, and then a line-block is made in the usual way. Where there is a series of maps with a common shading system, another economy is to use a single key on the first map in the series, to which reference may be made in successive maps.

Legends

The legend or caption can be conveniently mentioned at this point. A map, with its key and legend, should be complete in itself and self-explanatory, although to maintain the strict essential liaison between text and maps, the relevant places in the text should carry a reference, as "(Fig. *X*)". The legend should be carefully compiled. It must state the source of information, unless the map is wholly original, or give the exact reference to the statistical data on which the map is based. Any expansion of key definitions and any significant comments will follow. On a manuscript map, this caption may be typed on white paper and then stuck centrally below the map. A caption for a line-block in a printed book should be set up in a smaller fount of type than the body of the text.

The North Point

As a rule, a north point is not necessary when a map is drawn conventionally with the north at the top margin. But a point should be inserted on port-plans, town-plans and the like, where frequent references to directions are needed. The old map-makers lavished great skill on highly ornamental north points and compass-roses (Fig. 178), but a simple arrow, with a clean barb and a short cross-stroke midway across the vertical shaft, discreetly placed near a side margin, is quite adequate.

Lines of Latitude and Longitude

Many a good map has been spoiled by the superimposition of a heavy graticule or network of lines of latitude and longitude. For ordinary distribution maps, in which towns and coastlines are clearly marked, lines of latitude and longitude are unnecessary, although sometimes, as in the case of ocean-route maps, or of maps where an unusual projection has been used, the graticule must be drawn over the face of the map in some detail. Occasionally it is sufficient to mark off the degrees of latitude and longitude on the frame of the map.

Grid Lines

In the case of maps which are based on a topographical series with a local or a national grid, reference lines marked on the map are preferable to lines of latitude and longitude. Here again, grid lines need not be drawn across the map, but grid references may be marked off along the frame, or, in the case of small areas, at the four corners.

SYMBOLS

An immense variety of symbols can be used to specify distributions at particular points; Fig. 8 illustrates a number of these, but many others can be devised. They may consist of solid or outline geometrical figures, placed as near as possible to the centre of the place each is intended to indicate. They may be conventional,[1] or they may be chosen arbitrarily by the compiler to denote some specific feature. Pictorial symbols may occasionally be used effectively, though with discretion, particularly on the more graphic type of map;[2] thus bales, sacks, sheaves or barrels may indicate with some relevance the distribution of certain commodities. Litteral symbols (initial letters), possibly of a size more or less roughly proportional to the quantities represented, may be used, but these tend to give a somewhat confused appearance to the map, particularly when other lettering has to be inserted. All symbols must of course be carefully keyed.

Quantitative Dot Maps

The simplest form of symbol is the dot, and a very useful form of distribution map is one on which quantities or values are represented by dots of uniform size, each dot having a specific value.[3] This form of distribution map is especially useful when the values are distributed unevenly and sporadically, a fact which might well be concealed by some form of average density map. The dots are inserted within the particular administrative units for which statistics are available; obviously the smaller the statistical unit, the more accurate is the map. The first step is to examine the range of quantities involved, and then to select a value to be represented by each dot. The success of the map depends largely on the choice of this value; it should not be so low that there will be difficulty in inserting all the dots in units where the quantities are high, nor so high that there will be units with very

[1] See, for example, the U.S. Geological Survey Publication, *Topographic Map Symbols* (New York, 1950); and M. Couzinet, 'Le Problème de l'Uniformisation des Signes Conventionnels sur les Cartes Topographiques', *Comptes rendus du Congrès International de Géographie, Lisbonne, 1949. Tome I. Actes du Congrès. Travaux de la Section I* (Lisbon, 1950).

[2] D. L. Mumby, *Industry and Planning in Stepney* (Oxford, etc., 1951) uses pictorial symbols in a series of maps to denote industrial distributions.

[3] H. St. J. L. Winterbotham, 'Dots and Distributions', *Geography*, vol. 19 (London, 1934).

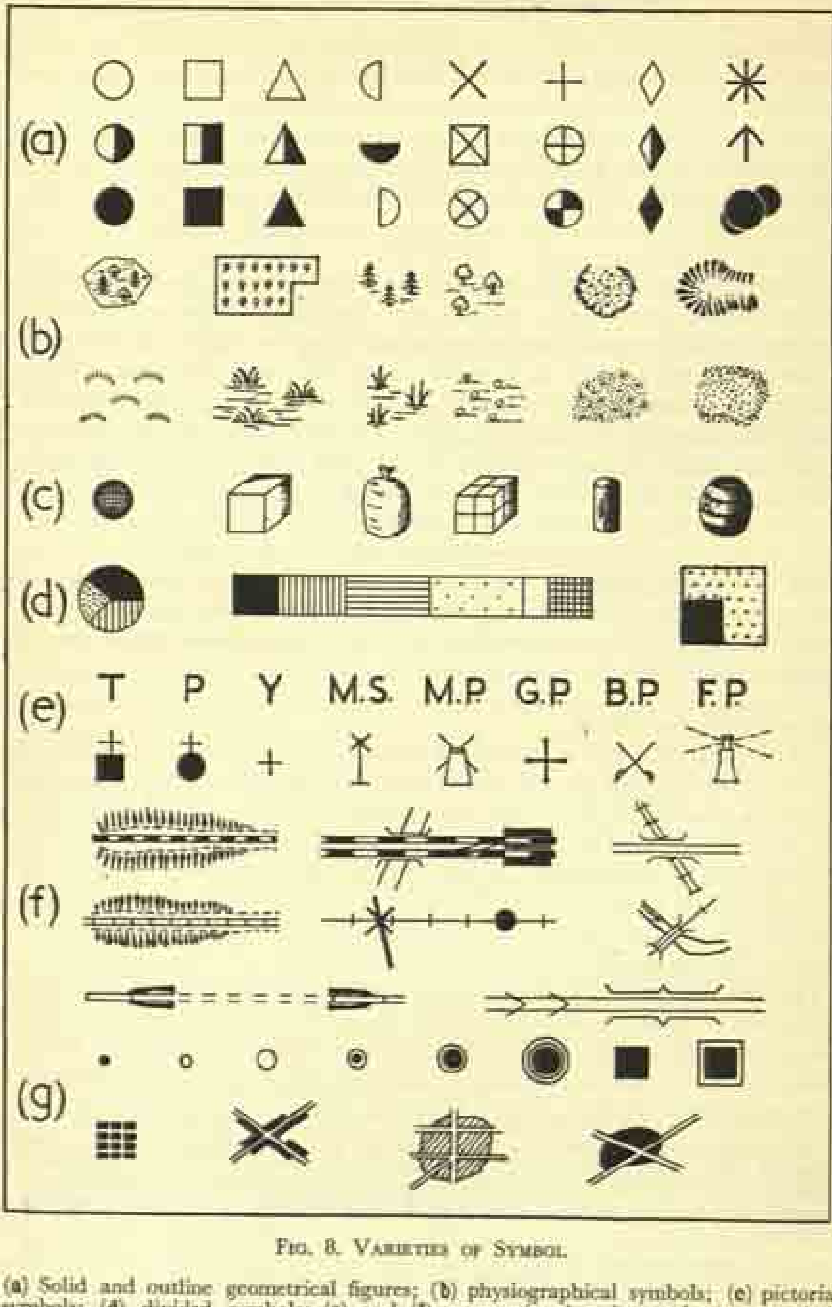


FIG. 8. VARIETIES OF SYMBOL

(**a**) Solid and outline geometrical figures; (**b**) physiographical symbols; (**c**) pictorial symbols; (**d**) divided symbols; (**e**) and (**f**) conventional point and route symbols adapted from the Ordnance Survey One-Inch and 1:25,000 series; (**g**) town symbols.

few dots. However carefully the value is chosen, it frequently happens that there will be problems attached to the placing of the dots in the units with very high or very low figures. In the former case, it may be found that the dots will be so numerous as to coalesce. Some cartographers, in fact, claim that this result should be aimed at; the contrast between the white (dotless) and solid black areas, with a gradual transition between them as the dots increase in frequency, is regarded as an ideal form of visual presentation. Other cartographers insist that the dots should be countable and therefore must not be allowed to merge. In practice, dots are rarely counted, for obviously the person in search of more precise information must return to the statistical source upon which the map is based; this, of course, should always be stated under the dot map. However, if the high values do produce merging, it may be preferable to fill the unit concerned in solid black, and then insert the actual value represented in figures in a white panel. In the case of units with very low figures, on the other hand, even when the value attributed to the dot has been chosen with discretion, a single dot may have to represent the total value within the whole of a unit. The problem is where to put the dot; obviously the map will here cease to have any precise locational value.

If dots are to be placed evenly and uniformly within each unit, as in the absence of more precise information they must be, the boundaries of the units should, strictly speaking, be included on the map; in practice, these are often removed after the dots have been inserted. But straight rows of dots should be avoided, and so should lines of dots parallel to the boundary of each unit, which will produce patterns and whorls in the finished map. The dots should be placed evenly by eye, and some continuity attained with the dots in adjacent units.

The dots may be placed more precisely when detailed information is available concerning the exact location of the values, derived from field-work, such as a land utilization survey for a crop map, or from larger scale maps, giving, for example, the actual position of hamlets and farms for a rural population map. But more generalized information, such as is provided by relief or climatic maps, or even by vague geographical preconceptions, must be avoided; "it is susceptible to wishful thinking, with some loss of objectivity. Sheep are not always found on uplands, nor barley in the drier parts".[1] Occasionally an assumption is warrantable; "in Arizona, alfalfa will be shown in the irrigated valleys and not in the arid uplands".[2] But such an assumption must be used with very great discretion (Fig. 109).

The actual size of the dots to be used presents a further problem.

[1] W. G. V. Balchin and W. V. Lewis, 'The Construction of Distribution Maps', *Geography*, vol. 30, p. 91 (London, 1945).

[2] E. Raisz, *General Cartography*, p. 249 (1st edition, New York, 1938).

Their size must depend on the scale of the base-map and on the number of dots to be inserted, but the dots must be neither so big that a coarse generalized effect is produced, nor so small that a blur is produced in areas of dense value.[1] A ball-pointed nib should be used to make dots of uniform size. Care must be taken when the drawn map is to be reproduced by means of a line-block that the dots are drawn sufficiently large to reduce, and the dots should be spaced rather more widely than might seem necessary on the manuscript map.

Instead of a pen, some form of stamp or die, using printer's ink, can be employed, and if the scale is large and the dots can have a diameter of one-tenth of an inch or more, small rotating compasses can be used to draw outlines which can be filled in with a pen or a fine brush. Yet another method, even more tedious than these, is to stick black dots, punched out of adhesive paper, directly on to the base-map.

Proportional Symbols

Some symbols can provide quantitative as well as locational information if they are drawn to scale. Circles, spheres, squares, rectangles, columns, triangles and cubes may be employed. The areas of two-dimensional figures such as squares or circles, or the volumes of three-dimensional figures such as cubes or spheres, are made proportional to the quantities they represent. A wide variety of these symbols may be used either as diagrams in themselves, or located on maps to illustrate population and economic distributions; it will be seen that many of the methods discussed especially in chapters V and VI rely on these devices. In addition to showing total quantities, they may be divided proportionally to give further information.

The Calculation of Proportional Symbols. If a quantity, say 10,000, is to be represented by a circle, the square root of the number must first be found, i.e. 100. The area of a circle is πr^2, but π is a constant and may be ignored. A circle can then be drawn with a radius some given length equivalent to 100 (e.g. 0·1 inch). If a second quantity, say 50,000, has to be represented, its square root is 223·0, and so on the same scale a radius of 0·223 inch must be used. This will obviously be a lengthy business if many quantities are involved, although a slide-rule will ease matters.

The most convenient method is to employ some form of scale from which radii of circles, or spheres, or sides of squares, triangles and cubes, can be measured directly or stepped off with dividers.

One method is to rule an evenly graduated linear scale, as in Fig. 9 (example A). Calculate the square root of several numbers (in this example 1, 3, 10, 40 and 100 were used), and draw from each of

[1] J. Ross Mackay, 'Dotting the Dot Map: An Analysis of Dot Size, Number and Visual Tone Density', *Surveying and Mapping*, vol. 9 (Washington, 1949).

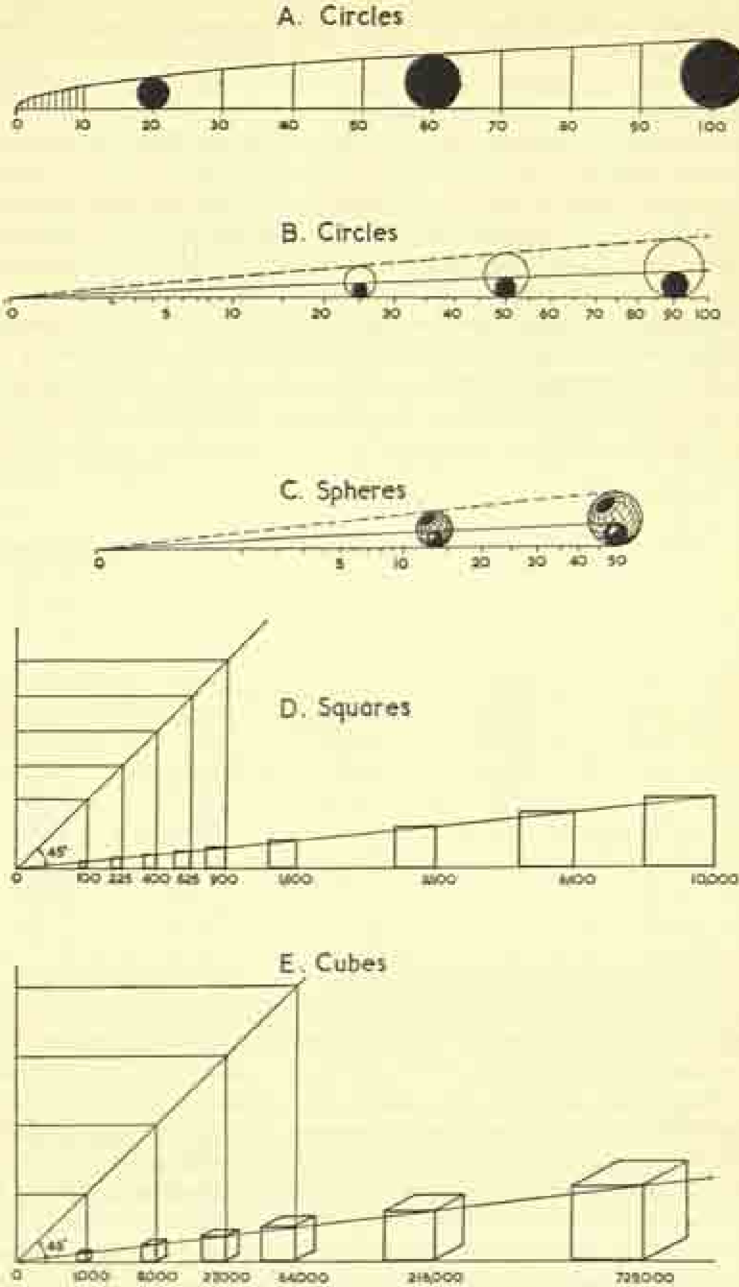


FIG. 9. THE CALCULATION OF PROPORTIONAL SYMBOLS

these points on the linear scale a perpendicular proportional in length to these square roots. The ends of each perpendicular are joined by a smooth curve. The diameter of a circle representing any intermediate value can be measured immediately.

An alternative method is to rule a line-scale, the divisions of which, measured from the zero on the left, are spaced at distances proportional to the square roots of the values (example B). This line may be of any convenient length; obviously a longer line will give a finer gradation between the values. Suppose that the maximum number to be represented is 100, then the length of the line is made proportional to the square root, i.e. 10. Intermediate square roots will be placed proportionally along the line, as shown in the following table, where the scale-line representing the value 100 is made 20 centimetres in length.

Number Represented	*Circles*		*Spheres*	
	Square Root	*Distance in cm. from zero*	*Cube Root*	*Distance in cm. from zero*
5	2·24	4·48	1·71	3·42
10	3·16	6·32	2·15	4·30
20	4·47	8·94	2·71	5·42
30	5·48	10·96	3·11	6·22
40	6·33	12·66	3·42	6·84
50	7·07	14·14	3·68	7·36
60	7·75	15·50	3·92	7·84
70	8·37	16·74	4·12	8·24
80	8·94	17·88	4·31	8·62
90	9·49	18·98	4·48	8·96
100	10·00	20·00	4·64	9·28

Draw an oblique line at any convenient angle through the zero, the angle depending on how big the maximum symbol is to be (example B). A vertical line drawn from the horizontal scale at any point to meet the oblique line will give the radius of a circle, the area of which is proportional to the number whose square root is represented at that point. Thus, briefly, using a table of square roots, put one leg of a pair of compasses on the zero, the other the correct distance along the scale-line (e.g. if the number was 35, distance on this scale=11·84 cm.), then swing the first leg vertically to the oblique line. This distance will be the radius of a circle proportional in area to the number it represents.

The same procedure may be followed to find the radii of proportional spheres (example C), but cube-root values have to be plotted on the base-line instead of square-root values, as shown in the table above. This type of scale may easily be adapted to plot proportional squares and cubes (examples D, E).

The Drawing of Symbols

Symbols must be carefully selected and drawn so that they are readily distinguishable, and, particularly when intended for reduction, each must be sufficiently large to reproduce clearly. Sometimes minute black squares, discs and diamonds are indistinguishable on printed maps because of over-reduction. They must first be carefully plotted in pencil, their outlines inked in with a ruling-pen or compasses, and then blacked in with a fine brush or broad *Uno* pen, unless outline symbols are required. It is preferable to ink in the symbols before other line-work and lettering is completed, so that they may be left clear to avoid blurring upon reduction. Figs. 98 and 99 exemplify the use of varied symbols to illustrate particular distributional patterns.

It may be well worth the expense of having a celluloid stencil cut to order with the outlines of a number of the more common geometrical symbols, in several sizes. A compiler should, of course, maintain consistency of symbols throughout a particular dissertation or monograph, and a stencil is a great aid to this end.

Line-Graphs and Diagrams

In its broadest sense the term 'graph' is used to denote divided circles ('pie-graphs' or 'wheel-graphs'), 'unit-graphs', 'bar-graphs' (i.e. columnar diagrams), 'star-graphs' or 'clock-graphs', and dispersion diagrams, as well as ordinary line-graphs, such as frequency graphs, probability curves and so on. In this book a distinction is made for convenience between *line-graphs*, in which a series of points is plotted by means of co-ordinates and then joined by a line, and *diagrams*, in which various graphical devices such as columns, rays and sectors are employed.

Line-Graphs

The conventional Cartesian type of line-graph is that in which a series of points is plotted by means of rectangular co-ordinates. The abscissae are measured on a horizontal and the ordinates on a vertical scale. One scale may represent a series of equal time divisions (independent variables), the other a series of quantitative or percentage values (dependent variables). Less conventional, but with a special

application to certain geographical problems, are polar, or circular, graphs in which the points are plotted by two co-ordinates, one an angle or bearing (the vectorial angle), the other a distance from the point of origin (the radius vector). A further type of line-graph is that in which oblique co-ordinates are used for plotting points. Where three oblique co-ordinates are employed, the graph is usually referred to as triangular.

In each of these line-graphs, the line joining the points is referred to as a curve. But this curve is frequently only a visual aid to overall changes in value and is not coincident with the true locus. The practice of joining points by smooth curves should therefore be avoided as far as possible. Curves can be smoothed by the employment of statistical methods, such as curve-fitting, but unless such methods are employed points should be joined by a series of short straight lines. Where continuous readings such as weather records yielded by thermographs and barographs are available, the resultant curves will, of course, be true line-graphs.

A *simple line-graph* shows only a single series of values, connected by one line. A *polygraph* or *multiple line-graph* (Fig. 76) includes several sets of values connected by distinctive lines, usually involving some direct comparison. A *compound line-graph* (Fig. 116) (known also as a *band-graph* or an *aggregate line-graph*) shows trends of value in both the total and its constituents by a series of lines on the same frame; the area between two successive lines may be shaded distinctively.

The Construction of Line-Graphs. The series of figures to be graphed is examined, and the maximum value noted, for on this and on the available size of paper depends the vertical scale to be adopted. The top of the vertical scale should just exceed the maximum value. The whole vertical range of values must be represented when zero is significant, even at the cost of a considerable empty space at the bottom of the graph, since a false impression of relative variability in the trends of the lines may be given unless the whole range can be appreciated. A vertical line is ruled on either side of the horizontal scale-line, and the equal intervals representing quantities are marked by neat ticks.

The plotting of these various graphs must be carried out on accurately ruled graph-paper. It is preferable, however, on completing the plotting, to trace off the graph-lines, the frame and the scales, using tracing-paper and a ruling-pen. This gives a cleaner finish and combines the accuracy of plotting which graph-paper allows with the clarity of white paper unobscured by the close and unnecessary grid of the graph-paper. Moreover, graph-paper is rarely of sufficient quality to take ink well, nor will it reduce clearly, particularly if it is ruled in faint coloured lines. A more open grid of perhaps half-inch squares

may occasionally be added to help the eye to follow the lines across to estimate the values involved.

The frame and grid of the graph must be ruled as lightly as possible, while the graph-lines will be made considerably heavier. Several different varieties of line (Fig. 2) can be used in drawing polygraphs. Care must be taken in scaling the values on the graph not to overload the figures; strings of noughts should be avoided on the vertical scale by, for example, lettering 'Thousand tons' at the top of the scale and numbering the units 1, 2, 3 and so on.

Diagrams

Columnar diagrams, sometimes known as bar-graphs, consist of a series of columns or bars proportional in length to the quantities they represent. They may be *simple*, when each bar shows a total value, or *compound*, when each bar is divided to show constituents as well as the total value. The bars may be placed either vertically (Fig. 119) or horizontally (Fig. 162), or in pyramidal form (Fig. 163); the first is usually most satisfactory when a time-scale is involved. After the scale of values has been determined, the exact length of each bar is computed and parallel lines are drawn; care should be taken not to make the bar too wide. It is preferable to leave a space slightly less wide than the bar itself between each, although in some cases, particularly for rainfall diagrams, there need not be any intervening space; these are often descriptively known as 'battleship-diagrams' from their profiles (Fig. 61). When the outline of each bar has been drawn with a ruling-pen, it can be filled, either in solid black or with diagonal shading. In a compound bar-graph, several shadings and stipples may be used (Figs. 162-5).

Divided Rectangles are akin to bar-graphs in that their lengths are directly proportional to the values they represent, but they are not plotted in series. When the scale is linear they are often deliberately widened in order to allow names and figures to be placed within the constituent divisions. The scale may, on the other hand, be areal, in which case the area both of the rectangle as a whole and of its divisions are directly proportional to the quantities they represent.[1] Either absolute values can be shown, or, for comparative purposes, the rectangles may be of uniform size and divided on a percentage basis.

Divided Circles, sometimes termed 'wheel-graphs' or 'pie-graphs', have much the same advantages as divided rectangles, in that they can provide striking proportional effects and can carry considerable information (Fig. 123). A circle is divided into sectors, each of which is proportional to the value it represents. It is convenient to work

[1] E. Raisz, 'The Statistical Rectangular Cartogram', *Geographical Review*, vol. 24 (New York, 1934).

with circular percentage graph-paper (see p. 153), on which 100 angles of 3·6 degrees each are set off from the centre of the circle. If only two or three major divisions are required, proportions of 360° may be easily calculated. Care must be taken with residual quantities; it is tempting to set off angles representing major divisions first, with the result that the cumulative error is felt most in the smallest section. Unless there is a composite category of 'Others', the small sectors must be measured and demarcated first, so that the cumulative error will be absorbed into the large sectors where its effect will be negligible. Care should be taken in lettering a divided circle, so that it is not necessary to turn the page around in order to read the names.

Star-Diagrams, sometimes called 'clock-diagrams', 'roses', or 'vector-diagrams', are a form of graph in which values are plotted as radii from a point of origin. This is especially useful where vector values are involved, as in wind-roses (see p. 154 and Fig. 82).

Dispersion Diagrams are of value where it is required to analyse the 'spread' or 'scatter' of a series of values. The basic principle is that a single dot to represent one value is plotted alongside a vertical scale. The dispersion diagram has a special application to the analysis of rainfall (see p. 158 and Fig. 84). In addition, it can be employed as an aid in determining critical values of density ranges for choropleth and isopleth maps.

Chorochromatic Maps

It is possible to compile and draw a wide variety of maps which illustrate spatial distributions. One group does not involve any consideration of quantities and values; thus the United States' cotton-belt can be outlined and tinted, and British coalfields can be delineated in solid black. Land utilization, soil and geological maps (Fig. 51) form a big proportion of these maps. The term *chorochromatic* can be applied to this category of map; in America it is often known as a 'colour-patch' map, the term colour being used in its widest interpretation of 'tint' or 'shade'.

Isopleths and Choropleths

Definitions

There are two main groups of maps which involve some indication of quantity as well as of spatial distribution, known as 'quantitative areal maps'. The first group includes maps where quantities are indicated by lines of equal value, such as contours and isotherms. The second group consists of maps which depict average values per unit of area over some administrative region for which statistics are available, such as density of population per square mile, the percentage of

land under cultivation, and the yield per acre of arable land.

It must be admitted that there is a considerable amount of confusion concerning the multiplicity of terms which have been coined to denote variants of these cartographical terms.[1] For example, to cover all lines representing constant values on maps, the terms *isopleth*, *isarithm*, *isoline*, *isobase*, *isogram*, *isontic line* and *isometric line* have been used at various times. J. K. Wright proposed that *isogram* be used for all lines of quantity, with two subdivisions.[2] The first group he called *isometric lines* (Greek, *metron*=measurement), a line such as a contour, an isotherm or an isobar "representing a constant value or intensity pertaining to every point through which it passes". The second group he called *isopleths*[3] (Greek, *plethos*=a multitude or crowd), "a line that represents a quantity or enumeration assumed to be constant, pertaining to certain areas through which it passes", such as lines of equal density of population.

Wright further suggested that the term *chorogram* be used to define all quantitative areal symbols, with two main categories, *choropleths* and *chorisograms*. He used the term choropleth to denote an areal symbol applied to an administrative subdivision, such as an indication of the density of population in a parish or county,[4] while he defined a chorisogram as a system of shading or colour applied for distinctiveness between two successive isograms. A further complication was introduced by a distinction between two other terms, *chorisometers*, where graded shadings and colours are put between two isometric lines, and *chorisopleths*, where these are put between two isopleths. One also comes across other formidable compound words, such as *chorisometrograms* and *chorisochores*.

This terminology is not as yet recognized as standard usage. In this book, the term *isopleth* is used in its broadest sense to embrace all lines of quantity, and *isopleth maps* will denote all maps on which isopleths appear, with or without tinting. The category of *choropleth map*

[1] Mention may be made here of a useful list of geographical terms, with their English-French equivalents, by A. Bargilliat, *Vocabulaire pratique anglais-français et français-anglais des termes techniques concernant le cartographie (géodésie, topographie, dessin, photomécanique, impression)* (Paris, 1944).

[2] J. K. Wright, 'The Terminology of Certain Map Symbols', *Geographical Review*, vol. 34 (New York, 1944).

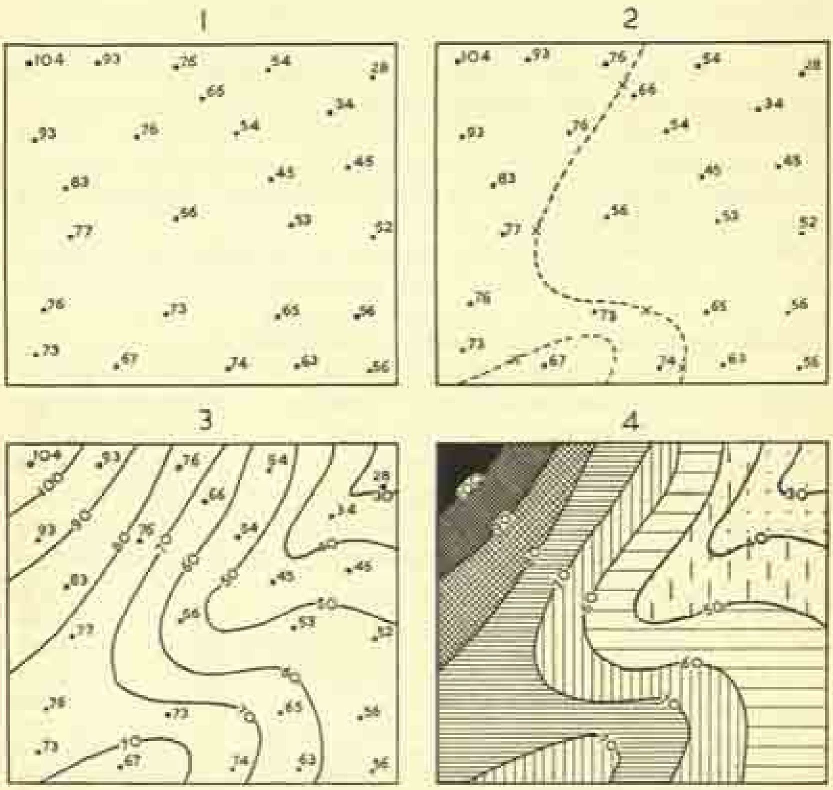
[3] See also 'Isopleth as a Generic Term', an unsigned note in *Geographical Review*, vol. 20, p. 341 (New York, 1930). J. Ross Mackay, 'Some Problems and Techniques in Isopleth Mapping', *Economic Geography*, vol. 27 (Worcester, Mass., 1951), also uses the term isopleth in the restricted sense suggested by Wright as a line passing through 'ratios for areas', thus showing ratios and not absolute quantities. He defines the 'quantity of an isopleth' as that of the areal strip through which it passes.

[4] E. Raisz, *General Cartography*, p. 246 (1st edition, New York, 1938), emphasizes that the term choropleth need not be limited to administrative divisions, but that a map divided into squares for which a density could be calculated and then tinted or shaded would also be a choropleth map. He suggested that a more restricted term of *demopleth* be used for those maps based on administrative divisions.

will be used for all quantitative areal maps, calculated on a basis of average numbers per unit of area.

Isopleth Maps

The contour-map is perhaps the most common example of an isopleth map, using the term as defined in its broadest sense. In addition, a wide



FIGS. 10–13. THE INTERPOLATION OF ISOPLETHS

1. The point-values are located; **2**, the critical isopleth of value 70 is interpolated, with the aid of crosses placed between pairs of values at a distance proportional to the value of each; **3**, other isopleths are similarly interpolated; **4**, a system of density shading is applied for clarity between the isopleths.

range of maps can be drawn, the basis of each of which is the plotting of values for as many stations as possible, and the interpolation of isopleths for specific values. These lines are either drawn through stations with identical values, or are interpolated proportionally between them

(Figs. 10–13). Thus the 50°F isotherm may be assumed to pass midway between two stations with average temperatures of 45°F and 55°F. These isopleth maps can be used to depict climatic distributions (isotherms, isobars, isohyets and isonephs), salinity of the sea (isohalines), and in fact any feature where figures are available and can be plotted for a series of particular points.

When an isopleth is used for a density or ratio map, such as the density of population or the percentage of arable land under a certain crop, the problem is rather more difficult. Control points have to be chosen as representatives of the various statistical divisions, the intervals between successive isopleth values must be carefully selected, and the isopleths must then be interpolated from the computed figure for each control point. The reliability of the ratios used must also be carefully considered.[1] This type of isopleth is used occasionally for various population elements, and the inherent problems are considered on p. 256.

Choropleth Maps

A wide variety of statistics may be used for the calculation and compilation of areal density maps. The actual administrative unit chosen as a basis depends upon the scale and upon the desired detail of the map. Thus a small-scale map of Belgium might be based on the average figures for the nine provinces, but a detailed large-scale map must use the figures for the 2,670 communes. Where the shapes of the administrative units are irregular, however, a misleading pattern may result. The narrow parishes of many parts of England, the long Canadian counties thrusting northwards into the Laurentian Shield, the minute communes of the Brussels agglomeration, and the large heathland communes of north-eastern Belgium, all may result in curiously artificial patterns on density maps. Conversely, the remarkably uniform shapes and areas of the French *départements* produce quite effective maps (Figs. 102–3).

It must be realized that these density maps, related as they are to the administrative units, reveal only average distributions over sometimes considerable areas. That being so, the misconception commonly arises that the grouping of a considerable unit under one average value implies distributional uniformity. This is in fact far from being the case, for the broad average may mask a vast range of local variations; obviously, the more extensive the administrative unit used, the more sweeping is the generalization presented in map form. Only occasionally can the compiler depart from administrative boundaries, when, by using detailed ground information, more accurate density boundaries can be computed (see p. 237).

[1] J. Ross Mackay, *op. cit.* See also W. D. Jones, 'Ratios and Isopleth Maps', *Annals of the Association of American Geographers*, vol. 20 (Lancaster, Pa., 1930).

The first step in the construction of a choropleth map is the calculation of the average density for each administrative unit. Density calculation is a laborious process, but it can be speeded up, either with the help of a slide-rule or by inspection from a graph. If three or more variables are involved, then a *nomograph* may be employed.[1] This is a graphical method of solving the functions of three or more variables (Fig. 14). The graph consists of three or more related scales,

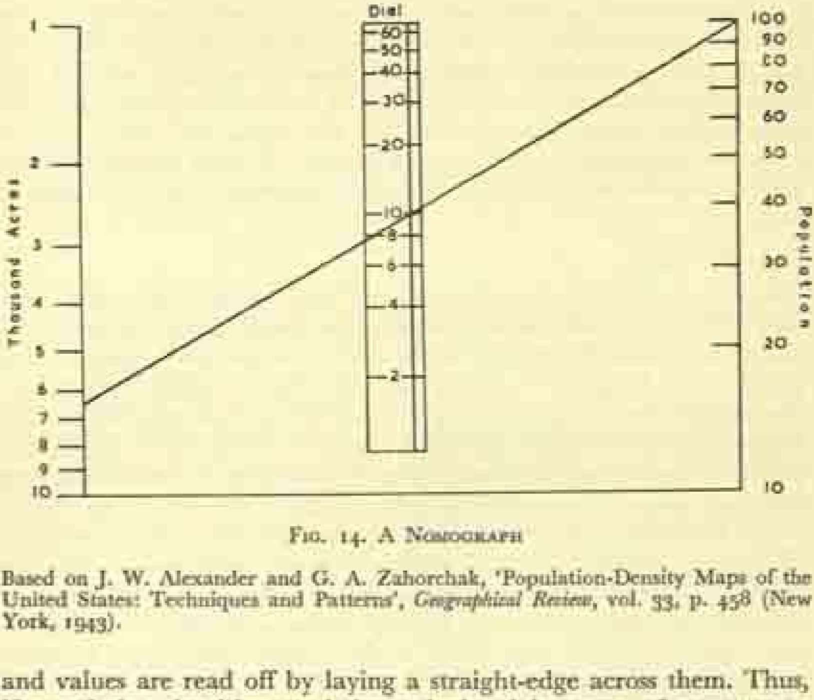


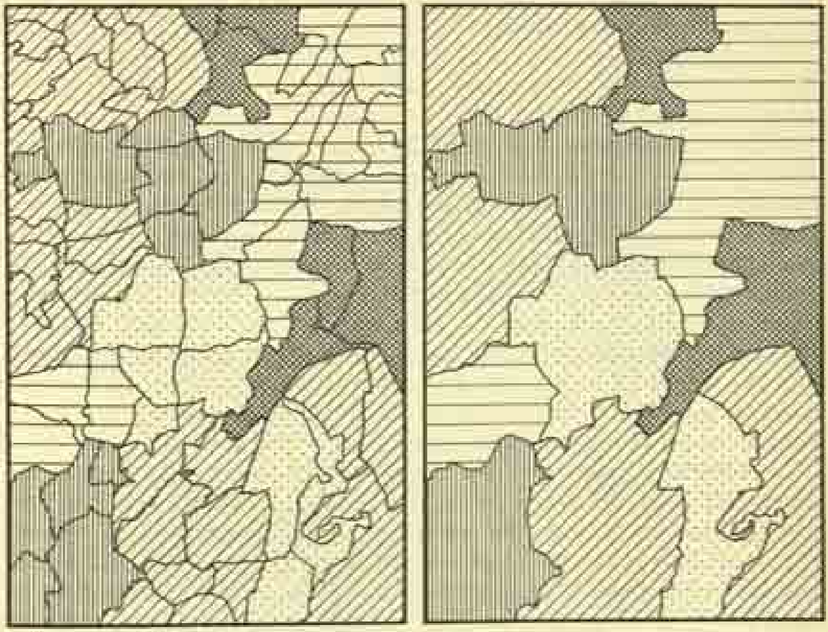
FIG. 14. A NOMOGRAPH

Based on J. W. Alexander and G. A. Zahorchak, 'Population-Density Maps of the United States: Techniques and Patterns', *Geographical Review*, vol. 33, p. 458 (New York, 1943).

and values are read off by laying a straight-edge across them. Thus, if population densities are being calculated in terms of persons per square mile for any administrative unit, and only totals of population and acreages are available, then a nomograph can be constructed. This requires the use of semi-logarithmic graph-paper, otherwise the graph will become too unwieldy. The acreages are plotted on the left-hand side of one-cycle logarithmic graph-paper, with values from top to bottom. The populations are plotted similarly on the right-hand side of a second sheet, with values from bottom to top. On a third sheet of two-cycle semi-logarithmic graph-paper, a scale of persons per square mile is plotted from bottom to top; this acts as a 'dial' which has to be set relative to the other two scales. In this particular

[1] F. T. Mavis, *The Construction of Nomographic Charts* (Scranton, Pa., 1948).

case, the dial is moved until the 10 on it is aligned between 6,400 acres on the left scale and 100 persons on the right scale, because 100 persons per 6,400 acres is equal to 10 persons per square mile. Once set, the nomograph may be used to calculate densities and to reduce acres to square miles in one operation.



FIGS. 15, 16. THE SHADING OF A CHOROPLETH MAP

In Fig. 15, the boundaries of the administrative units upon which the values are based are shown in full, but in Fig. 16 only those boundaries are retained which delimit the areas of the same value.

The next problem is the choice of a scale of densities; it is possible to obtain remarkably different impressions from the same statistics by changing the scale. This may be in arithmetical progression (0–100, 100–200, 200–300 per unit and so on), in geometrical progression (0–64, 64–128, 128–256 and so on), or at irregular intervals. The last is justifiable if it reveals significant features of distribution which would be lost by any regular scale. A dispersion diagram will help to show where significant groupings occur.

The Drawing of Choropleth Maps. The boundaries of the particular administrative units which form the basis of the density values are first drawn in pencil. A code number or letter (such as 1 to 5 or A to E

in a five density scale) is inserted in each administrative unit. When completed, it will be helpful to tint on the draft each category in crayon. Then the final drawing is made, outlining by a thin line each of the value-areas 1 to 5, and ignoring all other boundaries; as a rule, their presence spoils the density impression of the shading (cf. Figs. 15, 16). Occasionally, however, it may be essential for the map to show specific values for each administrative unit, in which case the boundaries may be retained.

Shading and Stipples

Shading Ranges

Tints of shading must be carefully chosen to distinguish a specific distribution on a non-quantitative map, or to bring out and emphasize the isopleth intervals, or to distinguish the various density ranges on a choropleth map. It must be emphasized that it is much more logical to shade uniformly on a choropleth map an area which has an average density of say 100 to 200 units per average area, than to shade uniformly on an isopleth map the area between the 100- and 200-foot contours, or between the 50°F and 60°F isotherms. In the first case, it is the actual area that matters, but in the second case the shaded spaces may distract attention from the isopleths themselves, and produce an effect of stepped areal distribution which does not exist.

To achieve a graphic effect, the density of the shading should be intensified with the increases in distributional values. Yet one frequently sees on a map, for example, two different density values represented by horizontal and vertical lines, each the same thickness and distance apart. This gives to the eye an identical, instead of a contrasting, shading density. Fig. 17 illustrates several alternative graded density ranges (examples A to F), of four, five and six depths, with and without black and white as culminating densities.

It must be emphasized that it is not always possible to judge the success of the map from the appearance of the shading range in a few small panels. It is useful to shade one or two sample portions of the actual map, choosing areas both of uniform and of diverse distributions. If a series of maps is to be constructed, it might well be worth drawing one map as a trial, and if it is to be reduced either photograph it down or have a trial block made, before embarking on the series. The maps reproduced in this volume are intended to serve as a guide to effective shading systems (see, for examples, Figs. 105–9).

Care should be taken to provide sufficient shading contrast; a balance must be maintained between dark and light tints, and any suggestion of a monotonous grey uniformity over the whole map is to be avoided. Solid black, used with discretion, helps to clarify a map, but the chief difficulty is to avoid the obliteration of line-work, lettering

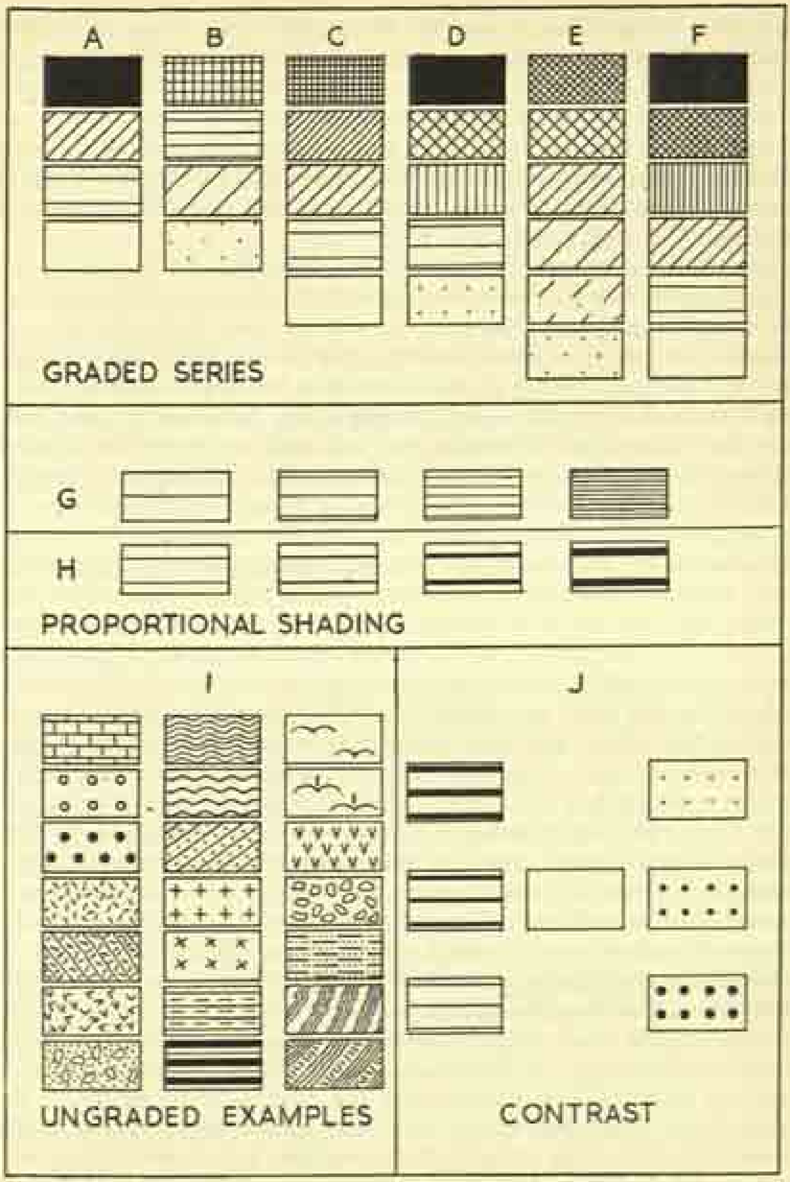


Fig. 17. Shading Systems

and other detail. Panels may be cut in the black areas or heavier shadings in which essential lettering has to be placed, but if there is much detail, line-shading must be replaced by some faint dot-stipple. The lowest value is commonly represented by blank areas. This is not altogether satisfactory, for it does give an impression of no value at all instead of a low density, and moreover it is often essential to leave the sea unshaded (occasionally the sea areas may be ruled horizontally with effect, as in Fig. 98).

Two shading ranges on Fig. 17 have been devised to provide an arithmetically correct proportion between the shading and the relative value each represents. This relation can be used when the range of values is not too great. Thus on a four-grade range (say 0–100, 100–200, 200–300 and over 300), horizontal lines may be drawn 10 mm., 5 mm., 2·5 mm. and 1·25 mm. apart (example G). Alternatively, the lines may be at a uniform distance apart, but each successive line is ruled twice as thickly as its predecessor (example H). However, as a general rule the compiler is aiming primarily at a striking effect, and this can be achieved without the finicky measuring necessitated by proportional shading. If the compiler ensures that the visual impression of each successive shading is approximately twice as dense as the preceding one, the result should be satisfactory. In addition, to ensure a clear visual impression between two successive shades, change the slope of the shading. Thus cross-hatching may be succeeded by closely ruled diagonal lines, and then in turn by even more widely spaced vertical lines. This will help enormously in emphasizing the pattern of the shaded areas. Care must be taken, when shading a map which is to be reduced, that lines are not ruled too closely, because blurring will take place either due to halation from photographic reduction, or when the line-block is inked; cross-hatching is particularly susceptible. For a reduction of two and a half times, lines should never be ruled more closely than at millimetre intervals. Double cross-hatching, such as a diamond pattern superimposed over squares, should as a rule be avoided for line-blocks; in any case, such elaborate shading usually takes more time than the results justify.

It is a moot point whether pecks and dots should be used in the same density range as line-shading. The effect of patches of dots between areas of line-shading may not always be pleasing; on the other hand, used judiciously dots may take a useful place at the lower end of a range (Fig. 137). Sometimes one series of lines and another of dots may be used to differentiate between two distinct features; thus on a map representing distribution changes over a period of time, the scale of increases can be represented by lines of varying thickness, of decreases by dots of varying size, and of little or no change by white spaces (example J, and see also Figs. 105–8). A few ungraded

shading systems are included on Fig. 17 for use in such non-quantitative distribution maps as land utilization and geological maps (example I, and see also Fig. 51).

Line-Shading Technique

When the pencil draft is complete, showing the isolines or the limiting administrative boundaries, and the range of tints has been chosen, the final draft may be prepared in ink. First draw in the coast, frontier and boundaries of shading. Then, using a ruling-pen set to the exact line thickness, rule in each shade in turn. It is extremely difficult to obtain absolute uniformity; lines must be strictly parallel, and the ruling-pen should never be allowed to run dry. A single line, slightly fainter or heavier than its neighbours, shows up most glaringly, especially upon reduction. A piece of graph-paper, over which the tracing is pinned, will help to maintain parallelism if a large area has to be shaded, or a parallel rule can be used. Different straight-line shadings in adjoining areas should be 'staggered' and not ruled continuously across the boundaries. Pecked lines may be drawn direct, but it is often easier to rule a continuous line, and then either scratch out or paint out with process white the blanks between the pecks.

Hand-Stippling Technique

Uniformity is extremely difficult to attain when stippling is done by hand. Where even shading should appear, one often gets the appearance of closer 'drifts' and conversely of blank patches, or the eye may pick out whorls and other patterns. Here again, the placing of the tracing over graph-paper will help, for the dots can be inserted over the exact points when the graph-lines intersect. On the other hand, when skilfully done, a casual placing of the dots may give a more even impression than would a strict alignment of the dots, but it needs considerable practice to achieve this.

When a stippled map is to be reduced, care must be taken not to make the dots too small. Minute dots are particularly vulnerable to the acid-etching process of the block-maker, and often are found to have vanished when the map is printed. Again, if the dots are placed too closely, blurring is likely, particularly if the printing paper is of not too good a quality. Here again trial and error is essential to determine working standards.

Mechanical Stipples

There are various methods by which shading and stippling may be applied mechanically to a map which is to be reproduced as a line-block. One method is to stick on to the manuscript map pieces cut to shape from a cellophane sheet, such as *Zip-a-tone*, on which the various

stipples are already printed. The disadvantage is that unless panels are carefully cut, the heavier tints will obliterate other detail, particularly lettering.

More commonly used is the system of mechanical stipples applied by the block-maker. *Tint-books* showing a wide range of stipples (known

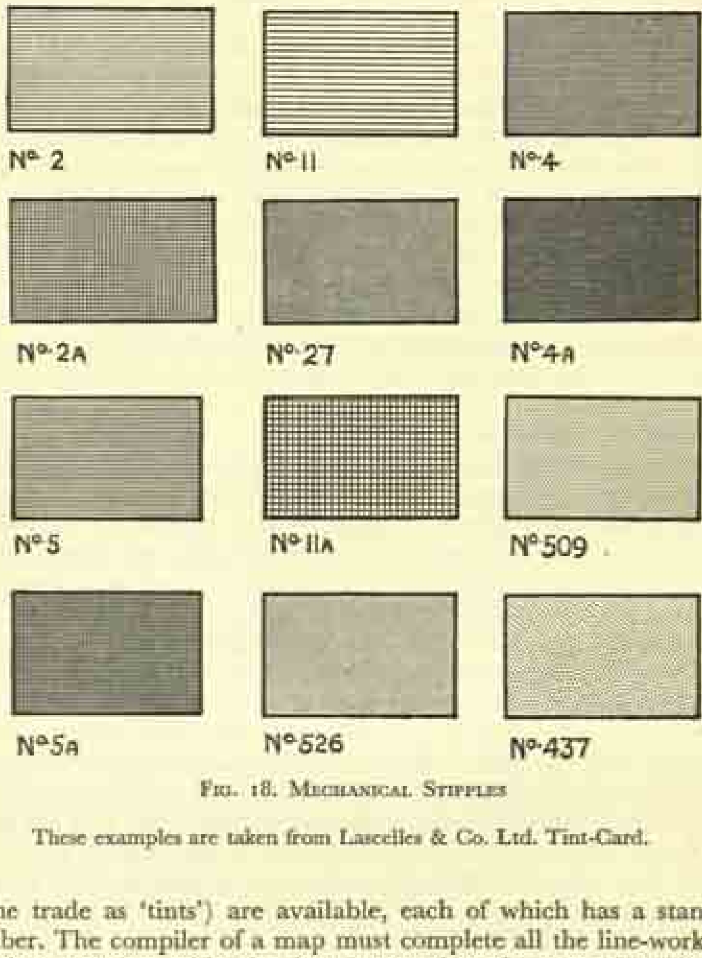


FIG. 18. MECHANICAL STIPPLES

These examples are taken from Lascelles & Co. Ltd. Tint-Card.

to the trade as 'tints') are available, each of which has a standard number. The compiler of a map must complete all the line-work and lettering, and then add a fine line surrounding the area to be stippled. This area should be lightly shaded blue (which does not photograph), on one side or other of the tracing, unless the areas concerned are particularly complicated in shape, when a transparent overlay on which the areas are separately shaded may be drawn, carefully ensuring

an exact register with the original. The reference number of the tint required must be added in the margin. If straight-line tints are desired, the angle at which the shading is to be laid must be indicated in the margin, either by ruling blue guide-lines or by specifying the exact angle to the vertical margin. Occasionally a graded series may be required, as on a relief map; this must be very carefully chosen from the available tints. From the sample tints shown on Fig. 18, for example, a reasonable series of four would be white, No. 509, No. 27, and black, which would provide more or less equal gradations.

Care must be taken with line-work and lettering when it is known that mechanical stipples are to be applied. In general, lines should be considerably thicker and lettering written more openly than usual. Many stipples simply obliterate underlying detail.

As a rule, this mechanical stippling should be used only when absolutely necessary. It is, of course, very expensive in proportion to the cost of the block, and results are not always satisfactory. The most successful and commonly used mechanical stipple in the Lascelles series is No. 526, which provides an even grey stipple, through which lettering and line-work appear clearly; it uses some 10,000 dots per square inch without blurring, even on quite poor paper. This admittedly could never be attained by hand.

The stipples are applied by the block-maker, after the photographic reduction of the manuscript map, directly on to the block, but before the etching process. It is therefore a highly skilled and expensive operation. The tint specified is cut out to the exact shape and applied to the block, an acid-resisting ink is rolled through the tint-sheet on to the surface of the block, which thus applies the tint, and the block is then etched in the usual way.

Colour

The Use of Colour

The use of colour is of great advantage in map-making, since not only does it add to the clarity and attractiveness of the map, but unlike black line-shading or stippling it does not obscure names and line-detail (Fig. 23). The printing and reproduction of colour-maps (such as those in atlases), using half-tone tints, is outside the scope of this work, but colour can be used in a limited way, on line-blocks, either by stipple or by line. If colour stipple alone is required, a single drawing is sufficient, on which the limits of the coloured areas are indicated by black lines, whether contours or any other isopleths, or the boundaries of administrative areas on a choropleth map. The areas to be coloured are marked with blue pencil, as for stipples on an uncoloured map, and the various tints are specified in the margin, with the name of the colour required (e.g. 'Brown' for relief maps)

placed beside them. The block-maker produces two blocks, one carrying the line-work in black, the other the stipple to be printed in colour; two printings are of course necessary.

If, however, it is desired to have in colour line-work, lettering, or, in fact, any other detail than a mechanical stipple, there are two possible methods. In the first, two or more drawings are needed, one for black and one for each colour; from one is made the black block, from the others the particular colour blocks, and the separate drawings are checked carefully for exact register. Alternatively, the map is drawn in black and primary colours, and the several colours are separated photographically by filter, thus enabling separate blocks to be made with a high accuracy of register. The maps can of course be printed in any colour.

These line-block colour-maps can appear in the text. This means that the sheet (i.e. 16 pages of text) will be run twice through the printing-press, once for each colour, so for economy as many as possible of the intended colour-maps should be placed on the same sheet. The method is obviously uneconomical for a single map. Alternatively, the colour map can be printed on a single sheet of glossy art paper and 'tipped in' (i.e. gummed in) by the binder. It must be emphasized that these colour maps are expensive luxuries, and should be used only when merited.

Colour, however, can be employed very effectively in the cartography note-book or in dissertations where only two or three copies are required and the maps can therefore be hand-tinted. The use of colour must not be overdone, however, as gaudiness can produce a most crude effect, and a pastel shade, emphasizing but not obliterating the line-work, should be aimed at.

Colour-Washes

The line-work must be finished in Indian ink, allowed to dry thoroughly, any pencil lines removed, and the surface of the paper dusted. Sufficient colour should be mixed for the whole map, and if possible a sample tint should be painted and allowed to dry for inspection. The chief difficulty is in laying a uniform wash over a large area; small patches of colour are comparatively easy to apply. The map should be put on a sloping board, and the paint laid on from the top downwards, brushed on in broad continuous free-flowing sweeps. The paint should be applied as rapidly as possible, consistent with precision, so that the edge never dries out. When the lower margin of the map is reached, remove the excess colour by running a dry brush along it. One practical suggestion is to remember to paint in the key-panel while using each particular colour; it is often impossible to match shades afterwards.

Allow the paint to dry thoroughly before applying an adjoining different colour or a further coat of the same colour if relative density layer-tinting is being attempted (see p. 61). One is frequently disappointed with layer-tinting; the result appears patchy and uneven, and touching-up usually makes things worse. Poor paper, uneven application, too heavy previous erasing which may have marred the surface of the paper, poor quality colours (especially greens), all these may account for the unsatisfactory results.

Lettering

A considerable proportion of the information presented on a map is conveyed by the lettered names. Moreover, the standard of appearance of the finished map depends to a large extent on the quality of the lettering; all too often fine line-work is marred by unpleasing lettering, or essential detail is obscured. Lettering is a fine art, and to attain real proficiency demands a long and patient training, so obviously a student cannot spend much of his limited time with the object of becoming such an expert. His aim should be to produce simple, quickly written, easily legible, yet reasonably attractive lettering. Using various aids, most students can achieve an adequate standard in a relatively short time.

There are many works on lettering as a fine art.[1] A study of the methods by which such topographical maps as the various Ordnance Survey series or atlas maps are lettered, may be helpful, if only to indicate the lofty standards at which to aim. But the problems of lettering maps to be drawn as exercises or to illustrate dissertations or even for line-blocks, are of a different order. This section is intended to do no more than to summarize the simpler methods available, and to give a few practical hints. Some of these principles, suitably developed, have been used to letter the maps which illustrate this book.

The Lettering-Mask

Whatever method of lettering is employed, a number of general points must be borne in mind. When the line-work has been completed on the preliminary pencil-draft, prepare a lettering-mask to fit

[1] Some useful works on lettering are as follows:

J. G. Withycombe, 'Lettering on Maps', *Geographical Journal*, vol. 72 (London, 1929).

C. B. Fawcett, 'Formal Writing on Maps', *Geographical Journal*, vol. 95 (London, 1940).

F. Debenham, *Exercises in Cartography*, chapter 8 (London, 1937), which is written especially for the student draughtsman.

A very full treatise on lettering is G. Hewitt, *Lettering* (London, n.d.), written primarily for craftsmen and professional letterers. It is, however, copiously illustrated, and the student cartographer can derive much benefit from it.

A. H. Robinson, 'The Size of Lettering for Maps and Charts', *Surveying and Mapping*, vol. 10 (Washington, 1950).

over the draft (mark the corner angles to give an exact register), which will indicate the positions of the various names. As far as possible, lettering should be placed horizontally for ease of reading; it ought to be possible to read comfortably all names on a map without turning it about. River names should be curved to follow approximately their courses; place each name on the north bank, unless the river is flowing north-south, when it should be placed along the west. Examine carefully the position of any larger names, such as those of countries; they should interfere as little as possible with other names or line-work, but should be spread out sufficiently to occupy most of the area to which they refer. Never allow names to interlace, nor space them so widely that the map appears to be dotted with odd unrelated letters. Make sure that it is absolutely clear to which feature or symbol a particular name refers. It may be necessary to alter the position of some names to avoid over-crowding; the location of a town-name, for example, can be transferred to the other side of its symbol, as long as it still clearly refers to it and to no other. When the mask is fully lettered, examine critically the appearance of the lettering as a whole, and see if a harmonious and balanced composition has been attained relative to the line-work. If too many names are included, the clarity of the map will suffer.

Next analyse the names—countries, oceans, mountains, rivers and towns—and decide on the form for each group, differentiating these on the mask itself. Thus countries can be shown by roman capitals, towns by roman lower case, seas by italic capitals, and rivers and lakes by italic lower case. Italics lend themselves surprisingly well to the curving necessary along rivers, although stencil italics are difficult to place on curves. When a series of maps is to be lettered, these contrasting forms should of course be standardized throughout.

Finally, the completed mask can be checked at this early stage for actual spelling mistakes, and also to ensure consistency with the text and with the policy adopted where there are alternative place-name forms.

Alignment, Size and Spacing of Letters

The next step is to draw thin guide-lines on the actual map for the letters; these may be in pencil, and two pencils can be tied together at the correct spacing. More conveniently, a celluloid stencil may be cut, providing several parallel lines at different intervals, and other lines at right-angles and at various slopes. Yet another device is to place a piece of blue carbon-paper, face up, under the tracing, and draw the guide-lines with a pair of dividers; this will provide fine blue parallel lines which will not photograph if the map is to be made into a line-block. The beginner must draw three lines if he is using lower

case letters, to delimit the base of the letters, the top of the lower case, and the top of the capitals. If stencils are being used, guide-lines are unnecessary except for the base-line of curved names. For horizontal names, the stencil is slid along a T-square or straight-edge in order to ensure perfect alignment. In addition to the horizontal guide-lines, it is very helpful to draw vertical or oblique guides in order to maintain a constant slope. With some experience, this will prove to be unnecessary, except at the beginning and end of a name in sloping letters.

The actual widths apart of the horizontal lines (determining, of course, the size of the lettering) is decided by a consideration of the number of names to be inserted, by the scale and extent of the map, i.e. the room available, and by the amount of reduction to be applied. The last is most important; frequently one can see a printed map, on the original of which the lettering had obviously been drawn much too small for the particular reduction, so that blurring and indistinctness resulted. It must be appreciated that if the map is to be reduced, the letters must be proportionally wider and more open, the spaces between greater, and the fine lines less fine, than if no reduction is intended. Italics especially must be made much rounder, and acute angles widened.

When guide-lines have been drawn in for every name, and any awkward or conflicting alignments adjusted, the names may be pencilled lightly in to obtain a correct spacing of the letters. This can only be done by eye; the space occupied by the different letters varies so much that mechanical spacing produces a displeasing effect.

Styles of Lettering

A style of lettering should be adopted which can be done naturally, and which is appropriate to the specific purpose. Find the particular nib which suits this style, and practise so that some degree of uniformity and speed is attained. Manuscript lettering may be divided into two groups. The first is lettering built up by multiple strokes of a broad stiff pen; the second is script lettering, in which each line consists merely of a single stroke of a steel or quill pen. The first method should be used only for titles and large names as it is a very slow process. A number of alternative styles is shown in Fig. 19.

In all cases, the form of the letters should be kept simple, neither distorted nor elaborated. Too severe and regular a style tends to make slight discrepancies stand out glaringly, but highly decorative styles, such as Old English (as conventionally used for antiquities) are hard to draw and are not very legible, nor do they reduce well. The extensive use of 'serifs' (the little ticks at the beginning and end of straight lines in letters) is generally to be avoided, as being time-wasting, and, moreover, if they are too exaggerated, they may mar the distinctive

MACEDONIA
Finland
ARABIA
Liverpool
BRADFORD
Warrington
MISSISSIPPI
River Amazon
PRESTON
Buntingford
PYRENEES
Brahmaputra
LLANGOLLEN
Finchingfield

forms of the letters themselves. Used with discretion they may help to draw attention from irregularities in a long straight line of letters.

Light and heavy lines should be kept consistent in thickness by maintaining a constant angle at which the nib is held to the paper. A stiff broad steel nib will be found most convenient; a springy nib makes uniform line thickness very difficult to attain. Some final hints are to keep the nib clean by wiping it on a piece of linen at frequent intervals, and to rest the hand on a piece of paper to keep the map unsoiled. When finally inking-in the letters, insert them before the line-work, so that it will not be necessary to erase any detail to clear the letters.

Quill-Lettering

A quill may be used very effectively instead of a steel nib for script lettering. The general effect is pleasing, while irregularities are not obvious, and with some practice a fair speed can be attained. It is possible for any student to produce quite passable results. It must be admitted, however, that quill-lettering is most effective when not intended for reduction. Often a beautifully lettered map, so attractive in its original form, is most disappointing upon reduction, for angles tend to blur, and the delicate differences in stroke-width are lost.

Stencil-Lettering

The use of stencils for lettering has much to commend it. It enables complete uniformity to be obtained, and where reduction is intended a little experience will readily show the exact size of lettering to be used for that particular reduction. Stencils can be obtained in a range of sizes, for upper and lower case, roman and italic styles, and also for numerals. A *Uno*-type pen should be used, so that by keeping the cylinder vertical the outlines of the letters can be followed exactly, and moreover the line thickness can be kept constant. Some stencils specify the size of pen to be used; it has been found by experience that for clarity and better proportions, especially with smaller letters, a pen one size less than that specified should be used. The ruling of a base-line and correct spacing by eye are as essential as for freehand lettering, especially when the name is to be lettered on a curve.

Fig. 19. Lettering Styles

The first four examples (capitals and lower case, in roman and italic styles) were built-up with a steel nib; the second four examples were written with a quill pen; the third group was drawn with the help of stencils, and then the ends of the letters were either trimmed with a razor blade or 'filled-in' to square them off. The last two examples were drawn with stencils, but using a finer nib than the makers specify.

Stencil lettering tends to leave rounded, sometimes 'blobby', ends to the strokes. This can be removed by 'trimming' the letters with a keen blade after the ink has dried, so giving a clean-cut precise finish to the lettering. However, if vertical strokes are trimmed, they will be shortened, thus throwing those letters out of alignment with the rest; the corners must be filled-in with a fine nib to produce a straight-edge base and so keep the correct height of each letter. If working on a surface such as drawing-paper, all corners and ends must be squared by filling-in, as trimming with a blade will spoil the surface of the paper.

The mechanical perfection of the guided letters, together with the individual judgement and taste needed for effective alignment and spacing, combine to make trimmed stencil-lettering a very convenient, legible and effective mode of lettering for maps intended to be reproduced as line-blocks.

Names in Type

For completeness, there must be mentioned the device of setting up the names required in type by the printer, or even on a typewriter. The names are then cut out and mounted on the map in their correct positions. On the whole, this method cannot be advocated, for the results seldom look pleasing or natural, as they present too rigid and unpliable an effect.

Reduction and Enlargement

Reduction and enlargement of maps can be carried out most expeditiously by photographic means (see p. 50). However, various graphical and instrumental methods are available, and their use forms a valuable cartographical exercise.

Graphical Methods

The Method of Squares. The original map is covered with a grid of unit squares, either by ruling faint lines on the map itself, or by laying over it a suitably ruled piece of tracing-paper, or a celluloid grid can be used. The closer the grid, obviously the more accurate will be the result; a one-inch map could carry a quarter-inch grid. Rule another network of squares, enlarged or reduced as desired, and copy the detail, square by square, by eye on to the drawing-paper, noting particularly any important intersections of detail with the grid lines.

It is, of course, the change of scale of the side of the square that produces the desired amount of enlargement or reduction. To enlarge three times, for example, the side of the square on the drawing-paper will be increased three times, that is, the area will be enlarged nine times.

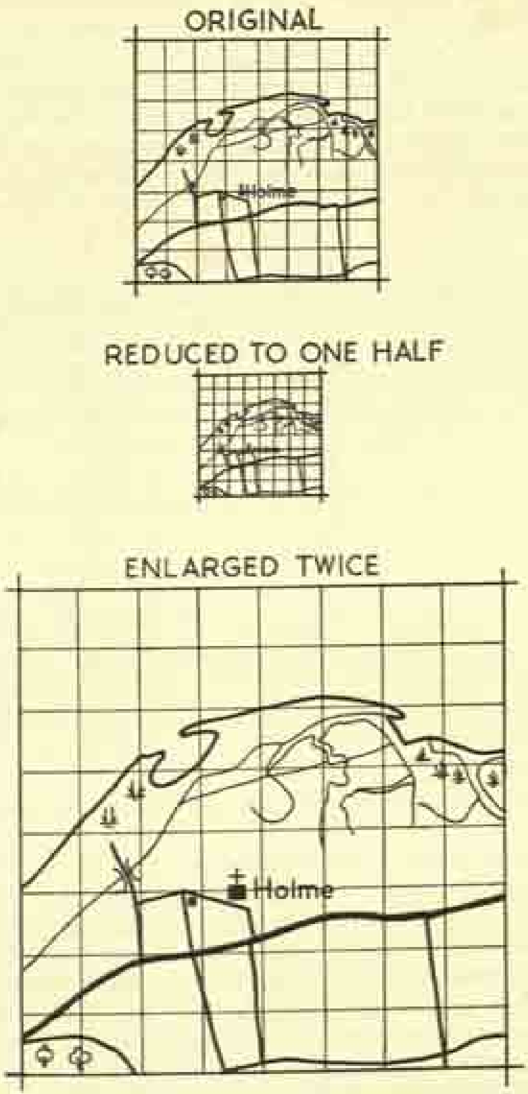


FIG. 20. REDUCTION AND ENLARGEMENT BY SQUARES

Care must be taken over the size of the conventional symbols. As a rule, unless the enlargement is very great, road widths and most symbols such as churches should not be enlarged; on the One-inch Ordnance Survey map most symbols are already exaggerated. Nor should lettering be increased proportionally. The finished enlargement should have as much balance as the original. Conversely, some detail on a reduction must be simplified, generalized, or even omitted. Examples of enlargement and reduction by the method of squares is shown in Fig. 20.

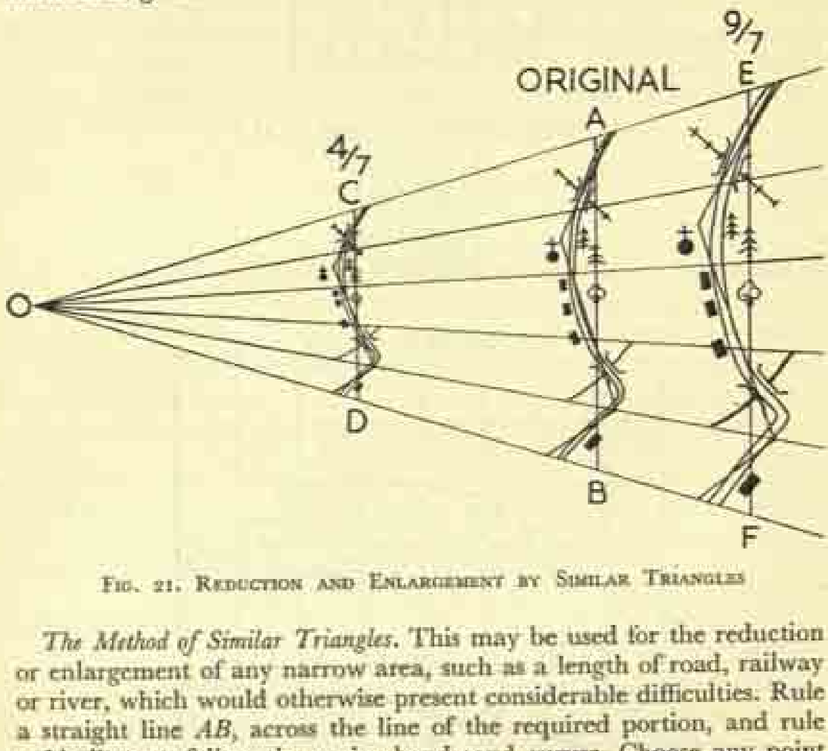


FIG. 21. REDUCTION AND ENLARGEMENT BY SIMILAR TRIANGLES

The Method of Similar Triangles. This may be used for the reduction or enlargement of any narrow area, such as a length of road, railway or river, which would otherwise present considerable difficulties. Rule a straight line *AB*, across the line of the required portion, and rule guide-lines to follow the major bends and curves. Choose any point *O* at a convenient distance from the line; the further away *O* lies, the more accurate will be the proportions obtained. Join each end of the section and any other significant points to *O*. If the desired reduction is, say, four-sevenths of the original, divide *AO* into seven equal parts, and find a point *C* which is four-sevenths of the distance from *O* to *A*. Draw *CD* parallel to *AB*, and also other lines parallel to the guide-lines along the section. The position of all important bends and other features will now be fixed along *CD*, and other detail can be drawn in by eye (Fig. 21). If enlargement is desired, produce lines

OA and *OB* proportionally, and find the position of *EF*, then draw in detail similarly.

Instrumental Methods

Proportional compasses can be used to simplify the copying of detail by the methods of squares or similar triangles. It is an instrument consisting of two bars, pointed at both ends, which act as dividers. These bars fit diagonally across each other, and are held together by a screw which slides in a groove down the centre of each bar. The screw is set to the proportion required, according to a scale-line on the top bar, and screwed down tight. If any distance is stepped off with the dividers at one end of the compasses, the dividers at the other end will give the same distance increased or decreased proportionally according to the scale-setting.

Two instruments are in common use for redrawing maps on a different scale, the pantograph and the camera lucida. The *pantograph* (sometimes spelt pantagraph) consists in its simplest form of four metal arms of equal length, loosely jointed at all corners but one, which is fixed to a weighted stand. A pencil is inserted in the corner diagonally away from the fixed corner. A cross-bar, the position of which can be adjusted to determine the scale-factor, can be moved along parallel to two of the sides. This cross-bar carries a second pencil held in a marker, which, when the cross-bar has been moved to the correct scale-factor, lies on the diagonal from the fixed corner. Thus if the line-work to be copied is traced carefully round by the marker on the corner, the pencil on the centre of the diagonal will draw the same pattern on the reduced scale. Conversely, if the centre marker is used to trace the line-work, the pencil on the corner will reproduce the same pattern on an enlarged scale. This instrument is quite useful for reduction, but any enlargement tends to emphasize and exaggerate inaccuracies.

More elaborate models are available, with little wheels for smooth movement, or with refinements to guide the tracer-point more smoothly, as in such patterns as the Coradi suspension model where the corners are held by taut wires from an upright arm to reduce friction. There is no point in describing the complications of these models; if the student wishes to use them, some practice following the maker's instructions will soon familiarize him with their operation. At one time, a pantograph was used very extensively by draughtsmen, but its use has declined since photographic methods have been developed.

The Camera Lucida depends on optical principles. The map to be copied is fixed in a vertical plane illuminated as brilliantly as possible, while the drawing-paper is laid in a horizontal plane. A prism, mounted on

an arm, is placed so that when the eye is put to it an image of the map appears vertically below the prism over the drawing-paper. The disadvantage of this is that if the eye is moved relative to the prism, the image will move relative to the pencil, so that distortion is difficult to avoid. The method should only be used for the very approximate copying, enlarging or reducing of a simple map; a large wall-map, for example, can be copied conveniently. To enlarge or reduce the original, the position of map and drawing-paper relative to the prism must be adjusted; if these distances are equal, the image will be the same size as the original, while if the drawing-paper is nearer, the image will be enlarged proportionally. Reduction is more satisfactory than enlargement, since the latter obviously increases errors.

Photographic Methods

A copying camera is a most essential part of a studio equipment. A half-plate camera, equipped with a ground-glass screen, and having at least a double extension and a 7- to 8-inch lens, can be arranged to move on runners about 12 feet long. By this means, maps up to about 4 feet square can be copied, and printed to any reduction. An enlarger capable of enlargements up to about 20 by 16 inches will enable negatives of photographed maps to be enlarged to a scale convenient for fine-drawing. Field-work plotted on a series of large-scale maps can be reduced photographically to transfer to the desired smaller-scale map. Moreover, if a map has to be made into a much smaller line-block, it is useful to have it photographed as an indication of the clarity of the lettering and shading.

Measurement of Area and Distance

It is occasionally useful during a course of cartographical exercises to be able to measure the area of any unit on the map with a fair degree of accuracy. Of course, when using administrative divisions as a basis for computations, the exact areas can be read off from the cadastral survey records, from large-scale maps on which areas are printed, or from census volumes. But when the student is dealing with a non-administrative unit, particularly in connection with land-forms, it may be necessary to compute the area; for example, the area within specific contours must be known in order to draw a hypsographic curve (see p. 86). There are several graphical methods, of a greater or less degree of accuracy, and various instruments which may be used.

The Method of Squares

A somewhat tedious procedure is to cover the area with unit squares, either by tracing the outline on to graph-paper, or by superimposing the graph-paper on the map over a brilliantly lighted tracing-table.

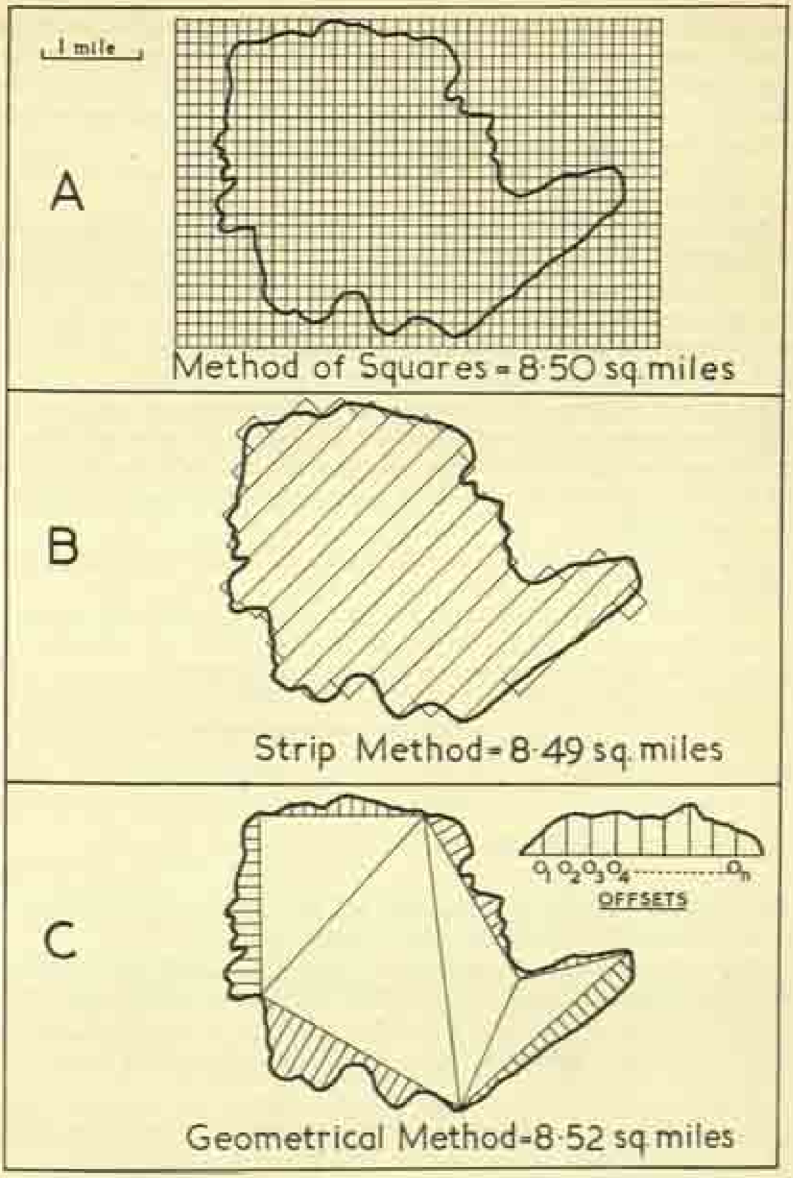


FIG. 22. MEASUREMENT OF AREA

Count the large squares, then the small; where the outline crosses a small square, include it if more than half its area lies within the outline. Apply the scale-factor to convert the area on the map into the area on the ground. Areas on a One-inch map can be readily measured on inch (and tenths) graph-paper (Fig. 22, example A).

The Strip Method

This is a more speedy method, but is not as accurate. Rule a series of parallel lines a unit distance apart, either upon the face of the map or on tracing-paper. The smaller the unit, the more precise will be the measurement, but it should be some convenient unit for the scale of the map; on a large area of a One-inch map, place the lines an inch apart. Rule vertical lines at each end of every strip to convert them into rectangles; the vertical lines should be placed as 'give and take lines' across each portion of the boundary so as to exclude as much area as they include (Fig. 22, example B). Add the lengths of all the strips, which will give the total area in square units, and apply the scale-factor.

Geometrical Methods

When an area has a relatively simple outline, divide it into triangles occupying as much of the figure as possible (Fig. 22, example C). Their areas can be computed by either of the formulae:

$$Area=\frac{Base\times perpendicular\ height}{2} \quad \ldots\ldots \quad (1)$$

$$Area=\sqrt{s(s-a)\,(s-b)\,(s-c)} \quad \ldots\ldots\ldots \quad (2)$$

where a, b, c are the three sides, and $s=\dfrac{a+b+c}{2}$

The problem remains of computing the area of the irregular portions along the margins; there are three possible methods.

Mean Ordinate Rule. Draw equally spaced perpendiculars (offsets) from the bounding lines of the various triangles to the margin of the area; the closer the offsets, the more accurate, if more tedious, the result. The area of the irregular portion can be computed from:

$$Area=\frac{l(O+O_1+\ldots O_n)}{n}$$

where l is the length of the line, $O, O_1 \ldots O_n$ are the lengths of each offset, and n the number of offsets.

Trapezoidal Rule. This method computes the area of each division bounded by two consecutive offsets. Its width is the length of the line

divided by the number of offsets, its length is the mean of the two bounding offsets.

$$\textit{Area of the first two divisions} = \frac{(O+O_1)}{2} + \frac{(O_1+O_2)}{2}$$

$$\textit{Area of the last two} = \frac{(O_{n-2}+O_{n-1})}{2} + \frac{(O_{n-1}+O_n)}{2}$$

The first and last ordinates will be used once, the others twice. The complete formula is therefore:

$$\textit{Area} = \frac{O+2(O_1+O_2+\ \ldots\ O_{n-1})+On}{2} \times \frac{l}{n}$$

This method will leave a small piece to the right of the last offset; the area of this can be estimated, or weighed against a similar piece elsewhere.

Simpson's Rule. Without entering into the geometrical complexities of the principles involved, the application of this formula will give a more accurate result than will the preceding methods. Divide up the bounding line into an odd number of offsets, so that there will be an even number of unit areas. The formula is:

$$\textit{Area} = \frac{l[O+O_n+2\ (\textit{sum of odd ordinates})+4\ (\textit{sum of even ordinates})]}{3}$$

It is to be doubted whether the mathematical tedium of this method is worth the slightly more accurate result.

Instrumental Methods

The most convenient instruments which can be used for the measurement of area include the computing-scale and several planimeters of varying degrees of refinement.

Computing-Scale. The computing-scale is a simple instrument which in effect applies cumulatively the strip method without the necessity of ruling vertical bounding lines or of measuring separately the length of each strip. It consists of a hard-wood rule, calibrated on its four edges (obverse and reverse sides) for the 1/2,500, 6-inch, 1-inch and ¼-inch scales, with a cursor which can slide from one end of the scale to the other. Rule a series of equidistant parallel lines over the area, and place the scale along the first strip, with the index wire over the position where the first vertical bounding line would fall, touching the zero of the scale. Slide the cursor along to the right-hand edge of the first strip, then move the rule to the second strip, and repeat this operation. When the cursor arrives at or near the end of the scale,

note down the reading and start at zero once more. When the cursor arrives at the right-hand edge of the last strip, note the final reading, and add it to all the previous ones. Some computing-scales are made to read off the area in acres for a particular scale, while others give an answer in square inches which must be converted into actual area measurements by applying a scale-factor.

Planimeters. Several makes of planimeter are available, varying from a simple form of tracer-bar, known as a *hatchet-planimeter*, to delicate instruments fitted with recording dials, known as *wheel-planimeters*. It is not easy to describe the theory of these instruments, but if the maker's instructions are carefully followed, a short period of practice will soon familiarize the student with their operation.[1] The principle of each model is that a point is carefully traced round the perimeter of the area to be measured. In the case of a wheel-planimeter, the dial records the distance travelled while tracing the perimeter, and this figure, multiplied by a known constant for the instrument, gives the area. Some models have a variable tracer-arm, which will allow direct measurement in any unit, others have a fixed tracer-arm which will give the area on the paper in square inches, and therefore a scale-factor must be applied.

Measurement of Distance

It is frequently necessary to measure the length of some irregular line on a map, such as a road, railway or river. If the line is not too irregular, a number of short straight portions can be stepped off successively with dividers, and summated. Alternatively, the end of a piece of fine thread is placed at the starting-point and then laid along the line, carefully following each curve. Again, a small toothed wheel fitted with a recording dial, known as an *opisometer*, can be run carefully along the line, the total length given on a dial is read off in inches or centimetres, and this is converted into actual lengths by applying a scale-factor. In each of these cases, it is well to measure the line twice, once from each end, and calculate the mean of the two results; this will balance 'inside' and 'outside' curves.

Each of these methods measures the length of the line as its projection on to a plane surface, which in hilly country will be considerably shorter than its actual length. If for some special reason a very accurate measurement is desired, it may be necessary to construct a profile of the road with no vertical exaggeration, and then to measure the actual profile.

[1] The clearest exposition of the theory of these instruments is given by F. Debenham, *Exercises in Cartography* (London, 1937).

CHAPTER II

RELIEF MAPS AND DIAGRAMS

An accurate topographical map can be used as the basis of much geographical work. The reading of a contour-map is not easy and needs considerable practice to enable the landscape to be visualized. In fact, the representation, recognition and description of relief features from their contour patterns, ranging from simple examples such as concave slopes, spurs and cols to complex land-forms, provides much of the content of map-work as generally understood. More advanced interpretation of topographical maps will help the student to examine and explain various geomorphological concepts. It is not going too far to say that the large-scale topographical map is secondary only to the ground itself in such work. As Professor A. A. Miller has said, "I referred to the map as a tool; in reality it is a whole bag of tools containing more ingenious devices than a boy scout's knife, and if properly used it will open almost any geographical problem. . . ."[1] But it must also be emphasized that the map must never be divorced from the ground. As W. M. Davis once somewhat ironically wrote, the study of maps "seems to lead different investigators to different results".[2] It is all too easy to read too much into, and to deduce unjustifiably too much from the map, without careful ground corroboration.

A geographer should also be able to add to a published map any further material he requires;[3] he "must supplement the map information with his own measurement of valley profiles, hill-slopes, etc., using levels, clinometers, aneroids, or field-sketching, according to the individual problem and the degree of accuracy required".[4]

A detailed topographical map provides, then, much definite and exact information which can be used as a basis for various purposes, "a starting point for further analysis".[5] Significant contours can be

[1] A. A. Miller, 'The Dissection and Analysis of Maps', Presidential Address, 1948, to the Institute of British Geographers, published in *Transactions of the Institute*, no. 14, p. 2 (London, 1949).

[2] W. M. Davis, 'The Peneplain', *Geographical Essays*, p. 353 (Boston, 1910).

[3] R. F. Peel, 'Geomorphological Fieldwork with the Aid of Ordnance Survey Maps', *Geographical Journal*, vol. 114 (London, 1949). As he says (p. 17), "[. . .] even the best [map] cannot provide more than a partial definition of the ground, or one more accurate than its scale will permit". The same writer strikingly illustrates his own precept in 'A Study of Two Northumbrian Spillways', *Transactions and Papers, 1949*, the Institute of British Geographers (London, 1951). He published a series of maps and profiles, based on large-scale O.S. maps, with additional details surveyed in the field; they include two contour-maps, with an interval of 10 feet.

[4] A. A. Miller, p. 2, *op. cit.* [5] A. A. Miller, p. 4, *op. cit.*

extracted; outlines can be traced as a basis for plotting field information; gradients, slopes and relative relief can be calculated; and profiles can be drawn.

One word of caution should be noted. A strict copyright exists in all official topographical and geological maps published by Government agencies, whether British or foreign. Permission is required for direct reproduction for publication of a portion of such a map; this as a rule is readily forthcoming, with the proviso, in the case of the British Ordnance Survey, that 'Crown Copyright Reserved' must be printed below. More doubtful is the common case when certain detail is extracted to be used as a base for a newly-compiled map. If it bears any resemblance to the original source, it is safer to consult the Ordnance Survey or other agency responsible.

The Depiction of Relief

Since the earliest days of map-making, the depiction of relief has been one of the major problems of cartographers, for it involves the representation of three dimensions upon a plane surface. From the primitive efforts, using crude pictorial symbols in profile or the so-called 'hairy caterpillars', to modern colour-printing, which employs several methods in careful conjunction, is a long story of trial and experiment, and of increasing technical efficiency.[1]

It is convenient to summarize in turn the main methods of relief depiction, indicating at the same time their application to the work of the geographer. It will be appreciated that the various methods, each with some advantage and usually with some limitations as well, may be combined with profit.

(a) *Spot-Heights*

At various points on the map, heights are marked which have been carefully computed relative to a chosen datum.[2] This datum for heights

[1] A very useful survey of modern aspects of the problem is given in 'Questions générales concernant la répresentation du relief au point de vue topographique et morphologique', *Comptes Rendus du Congrès International de Géographie, Lisbonne, 1949. Tome I. Actes du Congrès. Travaux de la Section I* (Lisbon, 1950).

[2] The Old British Datum was based on a series of short-term tidal observations carried out between the 7th and 16th March, 1844, at the Victoria Dock, Liverpool. Tidal observations for the ten days were taken at five-minute intervals for an hour about high and low water. Thus the Ordnance Survey obtained a datum, a Mean Sea Level, which held good until 1921, and indeed heights on some maps are still given in terms of the Old Datum, as the transfer is still in progress. When the O.S. decided in 1911 to re-execute the primary level network for Great Britain, it was also decided to obtain a new datum. Newlyn Tidal Observatory, on a pier projecting into the sea, had virtually an open-ocean site. From May 1st, 1915, to April 30th, 1921, the mean of hourly records was computed, and, after various corrections had been applied, a New Datum was determined as the basis for all heights in Great Britain.

above the sea is determined from a series of tidal observations, providing a 'mean sea level'. The datum for heights below the surface of the sea is usually taken on British charts to be the lowest water springs, i.e. the worst water conditions for navigation. The chief merit of spot-heights is that they provide definite and precise information, their chief defect is that distributed over the map they give little or no visual impression of the general pattern of the relief.[1] Used in conjunction with other methods, however, they provide that exactness which is otherwise often lacking. Prominent summits should have their heights marked, even on a small-scale map, and there should be a few heights in lowland areas and valley bottoms, so often ignored. Figures in areas of heavy shading should be inserted in white panels.

(*b*) *Contour-Lines*

Contour-lines or contours (sometimes known as *isohypses*) are drawn on a map through all points which are at the same height above, or depth below, a chosen datum. Some contours are surveyed in on the ground, others are interpolated, partly from accurately determined spot-heights, partly by the eye of a skilled surveyor in the field. These interpolated contour-lines are commonly known as *form-lines*, while the surveyed contours are thickened or emphasized in some way. Modern photogrammetric methods enable extremely accurate and rapid contouring to be carried out from air photographs, using complicated stereo-plotting machines.

The Contour-Interval. Occasionally a variable contour-interval may be used; it may be increased in mountainous areas above a certain height, or extra contours may be inserted, thus decreasing the interval, in lowland areas. Some authorities claim that this change of interval is permissible only on small-scale maps[2] (such as the International 1: Million series), or on atlas maps. On large-scale topographical maps the interval should if possible be maintained, even if the contours become crowded in mountain regions; this crowding, in fact, precisely indicates the steepness of the relief with some visual effect akin to that of hachuring. But such close contouring is seldom possible, or desirable, on manuscript maps. This problem of contour-interval is akin to that of all isopleth or choropleth intervals (discussed on p. 31).

[1] K. H. Huggins, 'The Scottish Highlands: A Regional Study', *Scottish Geographical Magazine*, vol. 51 (Edinburgh, 1935), uses a form of spot-height very effectively in an effort to demarcate the Highlands. On a map bearing only the 800 foot contour, he indicated with a dot each summit over 1,500 feet, to give a "crude indication of the degree of relief" (p. 299).

[2] One of the most attractive and informative relief maps produced is that of Belgium, the *Carte Oro-hydrographique*, compiled by A. de Ghellinck, M. A. Lefèvre and P. L. Michotte, printed by the *Institut Cartographique Militaire*. It is tinted in eleven shades, green, yellow and brown, at 5, 20, 50, 100 and every 100 metres to 700 metres.

Significant Contours. The topographical map provides detailed information about the relief, for every contour, corresponding to the particular contour interval, is included. In drawing a relief map for some specific purpose, it is usually necessary to select certain significant contours, partly for clarity and emphasis, partly for ease of drawing and reproduction. The contours must be carefully chosen; quite a different impression can be given by using an alternative series.

Sometimes a single contour is in itself highly significant. The 200-foot contour in the London Basin, the 70-metre contour in north-eastern Belgium, the 800-foot contour in Scotland,[1] the 1,300-foot contour in the Ingleborough district,[2] all these illustrate and emphasize some interesting feature.

Generalized Contours. As a rule, contours should be very accurately traced. Occasionally, however, a clearer picture can be obtained when minor detail is ignored. Professor S. W. Wooldridge, for example, produced a map of the Chiltern dip-slope in which he carried the contours, at 50-foot intervals, across the minor valleys which dissect the dip-slope, so as to link up the interfluves.[3] Needless to say, this practice should be used with great discretion.

Extrapolation of Contours. Under the guidance of an experienced geomorphologist, it is sometimes possible to reconstruct cartographically erosion surfaces or platforms which have been largely destroyed by subsequent dissection, and to insert the 'restored contours' or *eohypses.* Professor A. A. Miller[4] identified in the field the surviving portions of the 600-foot plateau in south-west Wales and plotted their margins at the point of the break of slope. These surviving portions of the plateau were stippled. He then extended the system of contours by extrapolation to show the probable original extent of the plateau.[5]

The Technique of Drawing Contour-Maps. The usual practice is to make a pencil draft of the contours which are to be shown, either deduced

[1] K. H. Huggins, *op. cit.*

[2] M. M. Sweeting, 'Erosion Cycles and Limestone Caverns in the Ingleborough District', *Geographical Journal*, vol. 115, p. 78 (London, 1950). Note the map of geomorphological features, outlining a striking erosion surface by means of the 1,300 foot contour.

[3] This map helped to bring out a broad bench, or flattening, between the 500- and 650-foot contours, with a steeper slope behind. Professor Wooldridge related this to the marine abrasion of Pliocene times. See S. W. Wooldridge and R. S. Morgan, *The Physical Basis of Geography*, p. 260 (London, new impression, 1946).

[4] A. A. Miller, 'The 600-Foot Plateau in Pembrokeshire and Carmarthenshire', *Geographical Journal*, vol. 110 (London, 1937).

[5] Striking examples of the use of contour extrapolation in the elucidation of geomorphological problems are given by H. Annaheim, 'Studien zur Geomorphogenese der Südalpen und Alpenrand', *Geographica Helvetica*, vol. 2, p. 90 (Bern, 1946); and by D. L. Linton, 'Some Aspects of the Evolution of the Rivers Earn and Tay', *Scottish Geographical Magazine*, vol. 56 (Edinburgh, 1940).

from photographs and models, surveyed on the land itself, interpolated from spot-heights, or traced from an official topographical map. Contours may be traced directly in ink from a clear topographical original. Indian ink should be used for a map which has to be reduced photographically, but coloured waterproof ink (such as red or brown) lends clarity to a manuscript map. A smoothly-flowing steady line is drawn, avoiding tremors and minute bends. Sometimes it is preferable to trace in the drainage first, so that the contour re-entrants can be exactly placed. The contours are numbered on the upper side of each line, which indicates at first sight uphill and downhill directions, placing the figures in a row above one another. Alternatively, the figures may be placed within breaks in each line, but the top of each must still be on the uphill side. The contour-interval should be stated below the map. When the map is to be reduced, the contour numbers and spot-heights should be drawn sufficiently large to reduce clearly.

(c) *Elaborations of the Contour-Method*

Various efforts have been made to introduce refinements into the representation of relief by contours. One experiment, tried by the Ordnance Survey and published in 1866, sought to make contours more striking by using white lines on north-western slopes and black ones on south-eastern slopes, superimposed over layer-tinting in grey. These contours were indeed so striking that they looked like a series of terraces.

The student can try the effect of 'illuminating' contour-lines with the aid of a tracing; go over the contours on the tracing, resting it on drawing-paper on a sheet of glass, with a hard pencil, which will make a slight indentation in the paper. Apply hill-shading (see p. 62) with a soft carbon pencil, which will make the contour-lines stand out in white. Finally, go over the contours on south-eastern slopes in Indian ink.

It is a criticism of contours that they give a somewhat smooth, rounded and rolling effect to the relief, while sudden changes of slope, sharp breaks or edges, and any interruption may be obscured, unless it is craggy enough to be shown by rock-drawing (see p. 64). R. Lucerna[1] superimposed heavy lines, known as 'edge-lines' or 'break-lines', to indicate these *Kanten* or edges, hence the German name of *Kantographie* and the American form Kantography. Some of these lines, indicating deeply cut lateral valleys, hanging-valleys or rock-steps, ran across the contours, others indicating rock-crests or river terraces were drawn parallel to the contours. The contour-lines were usually interrupted or broken at these edge-lines.

[1] R. Lucerna, 'Neue Methode der Kartendarstellung', in *Petermann's Mitteilungen*, vol. 74 (Gotha, 1928); and 'Kantographie', *Comptes Rendus du Congrès International de Géographie*, vol. 2, section 1 (Leiden, 1938).

It is a useful field-exercise for students to take an outline contour-map into some area of prominent relief, such as the Lake District. Work systematically over the ground, fixing break-lines and plotting them on the map; a major break can be shown by a heavier line than that used for a minor one.

Tanaka Kitirô's Methods. Two original methods of relief depiction, using contours as basic material, have been developed by Professor Tanaka Kitirô in recent years. These methods and the mathematics behind them are somewhat involved; they are described and very strikingly illustrated in several detailed articles.[1]

In the *Orthographical Relief* method, devised in 1931, he used 'inclined contours' to delineate the exact intensity of light and shade on the ground surface. These inclined contours, although mathematically determined, can be drawn mechanically and with precision by a draughtsman, and no judgement, estimation or artistic skill is necessary. It emphasizes steep slopes and striking relief extremely well, but the multiplicity of lines gives a heavy, even an obscuring effect, to the map. This is shown very obviously in the example specially drawn by Ordnance Survey draughtsmen of the country round Perth.[2]

In 1950, Kitirô published in America his *Relief Contour* method, which he devised in order to give the map an appearance of detailed relief as produced by oblique lighting, while preserving the outlines of ordinary contours. The exact thickness of each contour-line was calculated, varying according to the degree of slope. Contours on slopes away from the source of illumination were drawn in black, those facing the source of illumination in white; these he called 'relief contours'. All other detail—rivers, roads, cities, spot-heights and names—were drawn in black over the relief contours. The map can be reproduced either by a single half-tone block, or by two printing plates, one carrying the black contours and all other detail, the second with a uniform neutral background on which the white contours alone appear. The second process gives sharper line-detail than does the half-tone.[3]

[1] (*a*) Tanaka Kitirô, 'The Orthographical Relief Method of Representing Hill Features on a Topographical Map', *Geographical Journal*, vol. 79 (London, 1932).
(*b*) Tanaka Kitirô, 'The Relief Contour Method of Representing Topography on Maps', *Geographical Review*, vol. 40 (New York, 1950). Professor Tanaka Kitirô is a member of the Faculty of Engineering of Kyushu Imperial University, Japan.

[2] H. St. J. L. Winterbotham, 'Note on Professor Kitirô's Method of Orthographical Relief', *Geographical Journal*, vol. 80 (London, 1932).

[3] The student should examine the relief-contour map of the Kirishima volcanic group near Kagoshima in the island of Kyushu, published in Kitirô's article, and compare it with the reproduction of the official Japanese topographical map, on which the relief-contour map was based. The latter gives a curious appearance, as if it were built up of cardboard layers, but the relief effect, as applied to an admittedly striking area of volcanic topography, is extraordinarily vivid.

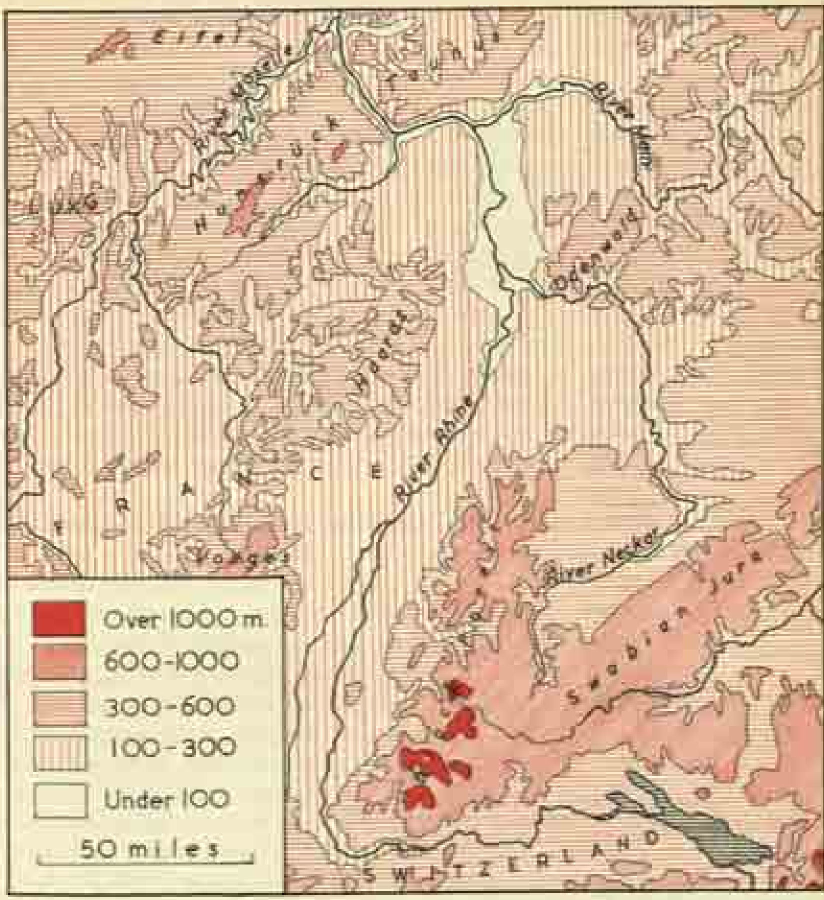


Fig. 23. Colour-Shading of Relief

(d) Layer-Shading and Tinting

It is possible to shade or colour each part of a map lying between two particular contours in order that the distribution of high and low land can be seen at a glance. This is known as layer-tinting, or as hypsometric-shading. It is obviously more useful for country of varied relief, for there is little point in tinting with one colour the whole of a map showing uniformly level country, whether on a plain or a plateau. The principle of layer-tinting is in a sense misleading, since a single shade between the 100- and 200-foot contours indicates a uniform level, instead of a progressive change in height. Nevertheless as in the case of all maps drawn on a similar principle (see pp. 34–7), the process is helpful if used with discretion.

Line-Shading. As a rule, line-shading and hand-stippling should be avoided for manuscript relief maps. It is slow to execute, a 'stepped' effect is unavoidable, and intermediate contours, lettering and other detail are often obliterated. Mechanical stipples, printed in black, may occasionally be used (see p. 37), but a carefully graded series must be chosen.

Colour. Modern printing processes have enabled layer-colouring to be employed very successfully on atlas and topographical maps, using half-tone blocks; these are obviously outside the scope of this book. Hand-tinting may, however, be used on manuscript maps, or by means of mechanical stipples on line-blocks (see pp. 39–40); if the cost is merited, a brown stipple can be extremely effective (Fig. 23).

The range of colours for hand-tinting of relief maps must be carefully chosen. One alternative is to use a sequence of greens, yellows and browns in ascending altitude, possibly culminating in red, purple and even white in high country. The contour interval at which the colour-change is made must be carefully chosen. As many depths as possible of each colour should be used to give a gradual sequence and to avoid the stepped effect of sudden contrasts. A second method is to use one colour only, ranging from the faintest to the darkest possible density.[1] A third method is to merge or grade the successive tints, so that a stepped appearance is avoided; it lacks the absolute quantitative nature of colour used as contour-filling (although it can be superimposed over contours), yet it is very effective, especially if combined with light hill-shading. The colours should be subdued in appearance, almost as if a pale grey wash were superimposed, so that a series might range from greenish-grey to greyish-brown. The key-panel consists of a single column, with merging colours, and with significant heights ticked off alongside.

[1] Examples include the purple layer-tinting on R.A.F. maps, the attractive greys of Bartholomew's *Road Atlas of Great Britain*, and the greys of the British Council's *Map of the Middle East*.

A most revealing exercise is to tint two copies of an outline contour-map, using two different colour systems; sometimes quite striking contrasts in the general appearance of the map will result.

(*e*) *Hachures*

Hachures are lines drawn down the slope in the direction of the steepest gradient; conventionally, they are drawn more closely together where the slope is steeper. Another method employs the same number of lines per inch, but each one is proportionally thicker, as in the Lehmann system, where the exact thickness of the individual hachure is determined according to the angle of slope. Another adaptation is where the hachuring is assumed to be obliquely lighted, usually from the north-west, but this is only effective in regions of strong relief, with sharply defined ridges, as in Switzerland, where the method was developed on the Dufour map.

The chief disadvantages of hachuring are the lack of absolute information (to meet which numerous spot-heights have to be inserted), the difficulty of drawing hachures in the field unless one has a very good eye for country, and the problem of distinguishing directions of slope. Most hachuring on modern printed maps is in colour, usually brown, purple or grey. This removes the grave disadvantage of the obliterating effect of black hachures in hilly areas, shown, for example, on the sheets of the first and second editions of the One-inch series of the British Ordnance Survey. On the other hand, its chief advantage is that it enables minor but important details, lost on a contour-map within the contour interval, to be brought out, and sometimes it can show country of striking relief in a very dramatic manner (Fig. 24).[1]

(*f*) *Hill-Shading*

Hill-shading, known in the United States as 'plastic-shading', aims at producing something of the effect of a relief model. It is imagined that such a relief model is brightly illuminated, either by a vertical source of light, or obliquely, usually from the north-western corner. With a vertical light, the steeper the slope the darker the shadow, while ridge-crests, plateaux, valley-bottoms and plains remain in the light. With an oblique lighting, north-western and western slopes are unshaded, while the eastern and south-eastern slopes are in shadow.

[1] Compare the hachuring on (*a*) the *Topographischer Atlas der Schweiz* (*Dufour*), 1:50,000; (*b*) the *Topographischer Atlas der Schweiz* (*Siegfried*), 1:50,000; (*c*) the new *Landeskarte der Schweiz*, 1:50,000; (*d*) the *Carte de France* au 80,000; (*e*) the 1st, 2nd and 3rd Editions of the One-inch series, Ordnance Survey; and (*f*) the 5th (Relief) Edition of the One-inch series, Ordnance Survey. The last of these, with contours in brown, took the hachures from the copperplates of the 3rd Edition, and printed them in orange on north-western slopes and in grey on south-eastern slopes.

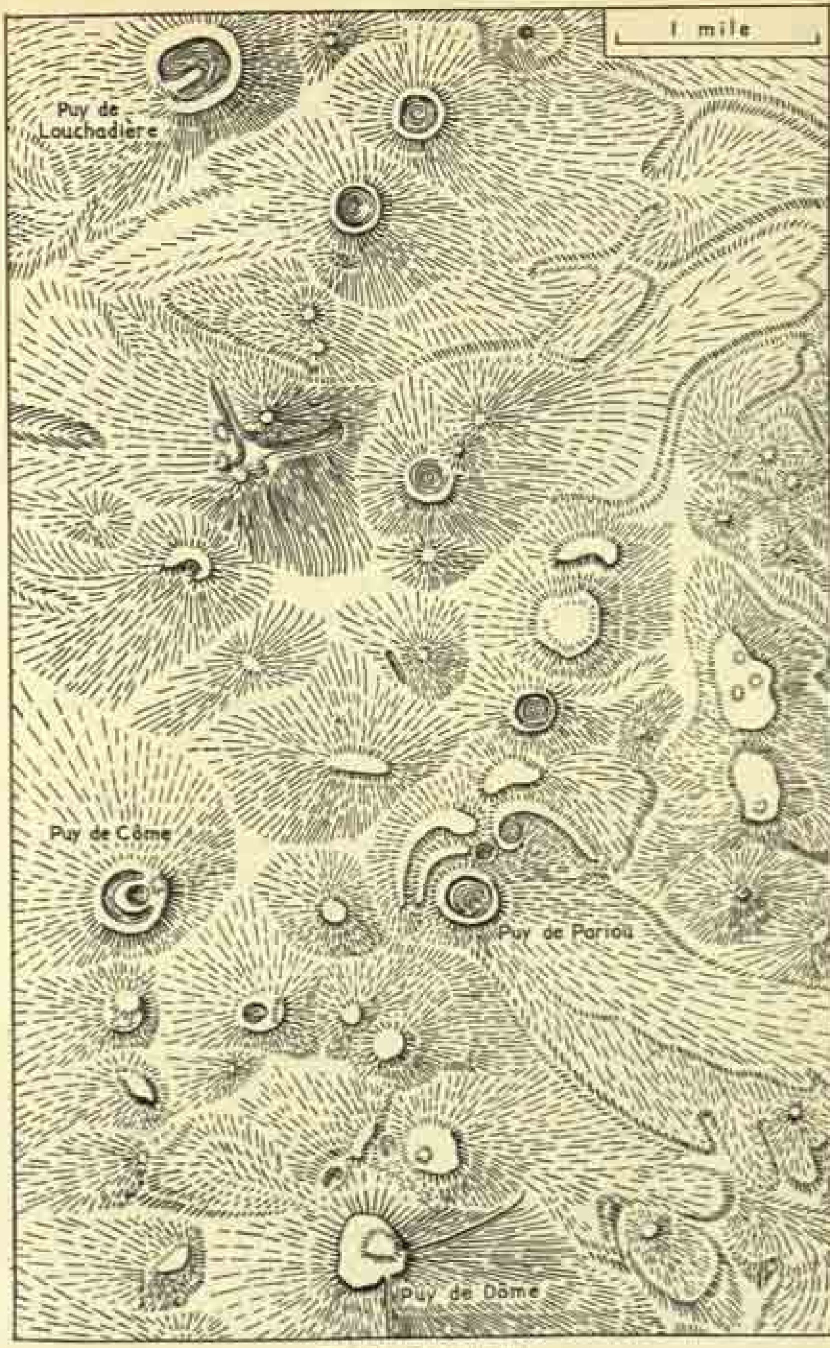


FIG. 24. HACHURING

Based on the 1:80,000 series, *type 1889*, *Service Géographique de l'Armée* (Paris).

Lighting from the south gives a curiously 'photograph-negative' appearance, and is never used. Grades of grey are used for shading, but occasionally in regions of striking relief solid black shading can be used for the areas in shadow, producing a very effective, if somewhat stark, effect.[1] It is impossible, of course, to add any more detail or lettering over such shading. Some of the disadvantages inherent in this method are common to those of hachuring: lack of specific information (unless there are many spot-heights); doubt about which is uphill and downhill, spur or valley, plateau or plain; and confusion about the relative steepness of slopes, particularly with oblique lighting.

The printed topographical map can, however, make quite effective use of hill-shading, when it is applied in a subdued stipple in some neutral tone, and used in conjunction with contours, hachures or both.[2]

In order to appreciate the problem of hill-shading, choose some clear-cut relief feature, such as a volcanic cone, or a fretted ridge, draw a contour-map of it, and then try to produce a shaded map. The shading may best be done by using a very soft graphite or carbon pencil; apply light strokes on the slopes in shadow. The individual strokes may be obliterated into a uniform tone by rubbing with a stump of rolled paper, or even carefully with the finger-tip. The student may try the effect of a graduated colour-wash in brown or grey, but great care is needed to avoid patchiness. Damp the paper and before it dries apply all the colour, leaving no sharp edges.

(*g*) *Cliff- and Rock-Drawing*

It is very useful to be able to indicate on a map the occurrence of steep cliffs and rock-faces. This is done by wedge-shaped black lines, with the thin ends pointing down the slope, but it is very difficult to do on a manuscript map without giving a 'fringed' or 'tasselled' effect.[3]

[1] E. Eiselen, 'The Central Valley (of California) Project', *Economic Geography*, vol. 23 (Worcester, Mass., 1947), has four such maps, which show the relief of the state of California with remarkable clarity, emphasizing, of course, the longitudinal valley and the ranges on either side. Information concerning canals, reservoirs and irrigation projects, is lettered in panels outside the shaded area, and located by means of arrows.

[2] The French *Service Géographique de l'Armée* employed on the 1:50,000 series, published in the decade before 1914, brown contours at 10-metre intervals, with a double system of hill-shading. The shadow of a vertical lighting was printed in brown, that of an oblique lighting from the north-west in purplish-grey. The *Nouvelle Carte de France*, on the same scale, published after 1922, used for economy only oblique hill-shading from the north-west in brown.

[3] The Lake District and Snowdonia sheets of the One-inch (Tourist Edition) of the Ordnance Survey, some of the sheets of the Fifth (Relief) Edition, and the more detailed 1:25,000 series, show crags very effectively. The Swiss maps use beautifully drawn symbols, particularly the 1:50,000 *Siegfried* maps and the new *Landeskarte der Schweiz* on the same scale.

(h) *Physiographic Methods*

American geographers, particularly E. Raisz,[1] have devised methods of showing physiographic features on small-scale maps by the systematic application of a standardized set of conventional pictorial symbols, based on the simplified appearance of the physical features they represent as viewed obliquely from the air at an angle of about 45 degrees.

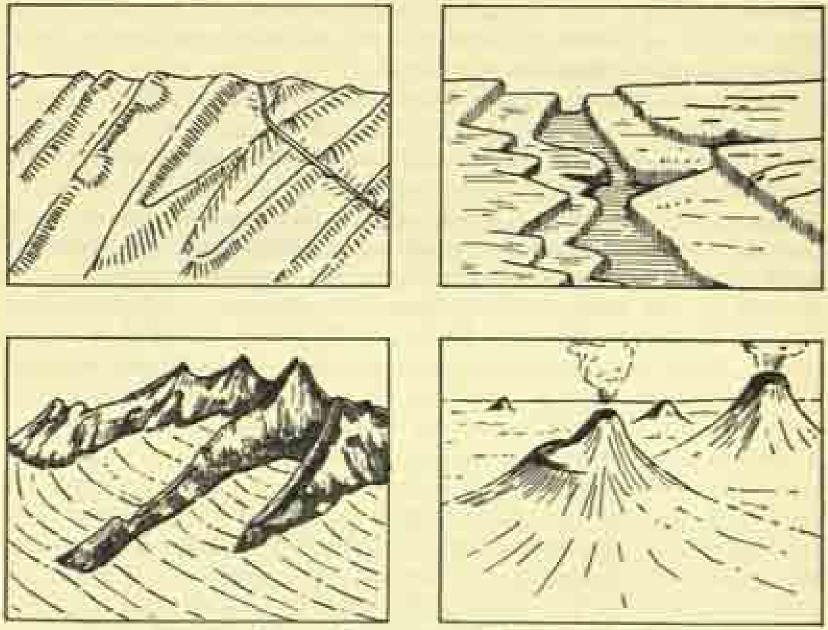


FIG. 25. PHYSIOGRAPHIC SYMBOLS

Based on E. Raisz, *General Cartography*, pp. 151–3 (New York, 1938).

Some American geographers call this a 'morphographic' or 'morphologic' method. In principle, the method goes back to the primitive concepts of early maps, whereby relief features were shown obliquely and in some degree of perspective, instead of by vertical conventions. Many of these physiographic symbols are derived from block-diagrams used by such pioneers as W. M. Davis. In the article quoted, Raisz standardized the symbols to be used into a set of forty 'morphologic types', and added a further ten, based mainly on natural vegetation, to diversify the category of plains. A few of the more striking symbols are illustrated in Fig. 25.

The advantages of this method are most readily appreciated when

[1] E. Raisz, 'The Physiographic Method of Representing Scenery on Maps', *Geographical Review*, vol. 21 (New York, 1931); and E. Raisz, 'Developments in the Physiographic Method of Representing the Landscape on Maps', *Comptes Rendus du Congrès International de Géographie. Amsterdam, 1938*. Tome 2. Travaux de la Section I. Cartographie (Leiden, 1938).

it is used for semi-diagrammatic small-scale maps, such as military maps to show a campaign, or for teaching purposes, for they do give a good broad impression of the country. Some American regional geographers, such as Preston E. James,[1] have made extensive use of the method. The chief difficulty is to lay these symbols, which in appearance are like block-diagrams and therefore are intended to be viewed obliquely, on to a map which has to be viewed vertically. The symbols can of course be superimposed on faint layer-tinting, or a number of spot-heights can be added.

An interesting application of the principle consists of making a large-scale geomorphological map of some striking piece of country, using physiographic symbols. Trace a contoured base-map from a large-scale topographical map. Then, with the help of geological maps, oblique air photographs if available, and field observation, draw in pictorial symbols, using the contours as a location guide. The symbols need not be restricted to Raisz's chosen forty; special symbols can be devised for the particular land-forms. For example, a physiographic map of Craven in the West Riding of Yorkshire would show scars, gorges, dry-valleys, pot-holes and water-sinks, monadnocks, areas of clint pavements, areas of peat bog, millstone grit 'edges', and so on. A physiographic map of Snowdonia would contain an immense variety of striking phenomena—glaciated valleys, hanging valleys, cwms, llyns, rock-steps, upland moors and arêtes. The area chosen need not be viewed so that the top of the map is in the north; for Craven this might indeed be the most revealing aspect, but for Snowdonia a view south-westwards across the Glyders towards Snowdon itself would be preferable. This work has much of the nature and quality of landscape-drawing and should preferably be carried out in the field.

(*i*) *Surface Configuration Maps*

A useful method of indicating relief features in a broad and generalized, yet striking way, akin to physiographic symbols, has been used by a number of American geographers, notably by P. E. James,[2] where

[1] P. E. James, *Latin America* (New York, 1942); and *A Geography of Man* (Boston, 1949). Note particularly in the latter the striking maps of the western Sahara (p. 41), the Tarim Basin (p. 52), South Africa (p. 56), India (p. 102), California (p. 124), Greece (p. 133), Italy (p. 148), and eastern North America (p. 235). Other very attractive examples are shown in articles by E. O. Teale and E. Harvey, 'A Physiographical Map of Tanganyika Territory', *Geographical Review*, vol. 31, p. 655 (New York, 1941); and by H. de Terra, 'Component Geographic Factors of the Natural Regions of Burma', *Annals of the Association of American Geographers*, vol. 34, p. 71 (Lancaster, Pa., 1944).

[2] P. E. James, *A Geography of Man* (Boston, 1949). Note the supplement of Reference Maps, pp. 583–618. P. E. James also produced in a previous work, 'On the Treatment of Surface Features in Regional Studies', *Annals of the Association of American Geographers*, vol. 27, p. 213 (Lancaster, Pa., 1937), a surface configuration map of Kentucky, on which he distinguished four categories: (i) flat-topped interfluves; (ii) colluvial slopes; (iii) residual slopes; and (iv) alluvial bottom-lands.

a physical background was needed for economic or ecological surveys. He divided the land surface of each continent into the following categories:

Plain	Hilly upland and plateau	Low mountain
High mountain	Hamada	Erg
Mountain and bolson	Intermont basin	Ice-covered area

To each category he ascribed a stipple or line-shading, and so produced a series of clear 'surface configuration' maps of the continents.

A simple configuration map is shown in Fig. 26. It was required to produce an outline relief map as a locational basis for a regional study of the Lötschenthal, a valley in the Bernese Oberland drained by the river Lonza, a right-bank tributary of the Rhône. The outline of the snow-fields and glaciers was abstracted from the 1:50,000 *Siegfried* map of the area, and then the main crest-lines were defined by heavy black lines.

Profiles

The drawing of a profile from a contour-map may be of very great assistance in visualizing the relief, and in the description and explanation of the land-forms. A geomorphologist in particular, seeking to analyse the nature of relief, is interested in surfaces with different slopes, corresponding to periods of peneplanation and of aggradation, but contour-maps often fail to bring out these significant surfaces. "Since the contoured map, while an indispensable aid to the geomorphologist, is incomplete in its indications, we may consider certain methods by which its testimony can be supplemented, rendered clearer, or translated into other terms. Such methods are, of course, no substitute for work in the field. They may, however, usefully precede such work and can also assist in portraying its results."[1] Various methods, often involving the drawing of some form of profile, may therefore be employed.

The terms 'section' and 'profile' are used with little precision and much confusion. The literal meaning of a section is a cutting, or a surface exposed by such a cutting, and the term is correctly used only when the geological structure is shown. A profile, on the other hand, is the outline produced where the plane of a section cuts the surface of the ground. A profile of a river valley, for example, may be either longitudinal or transverse; in the former case, it is the outline of the valley on the surface from source to mouth, in the latter case it is drawn across the valley at right-angles to its general direction.

[1] S. W. Wooldridge and R. S. Morgan, *The Physical Basis of Geography*, p. 259 (London, new impression, 1946).

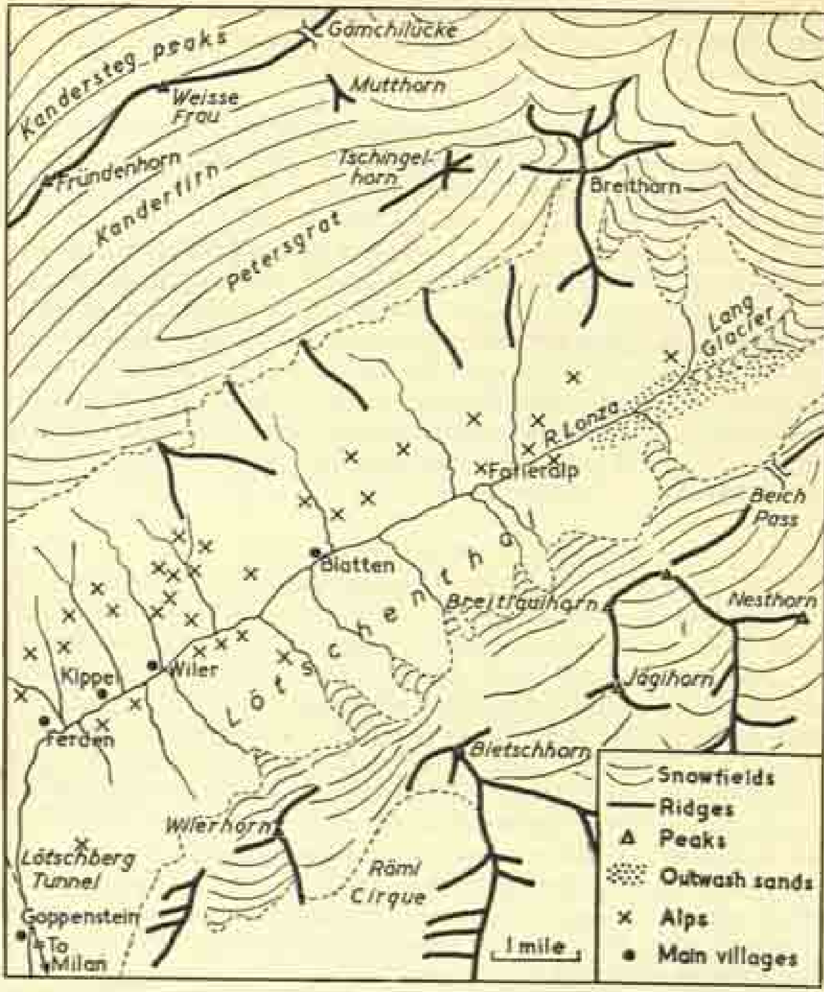


FIG. 26. A CONFIGURATION MAP

Based on *Topographischer Atlas der Schweiz* (Atlas Siegfried). The Lonza, rising in the snow-fields of the Bernese Oberland, flows through the Lötschenthal, and then joins the Rhône near Brigue. This map was drawn to emphasize the main features of the configuration of the valley.

The Drawing of Profiles

The first step in the drawing of an accurate profile is to lay a straight-edge of paper along the chosen line on the map, then mark accurately with sharp clean ticks all contour intersections, spot-heights, rivers, summits and other defined points Draw the base-line of the profile on a sheet of graph-paper, and transfer the ticks carefully to this. Rule vertical lines at either end of the base-line, and mark off a vertical scale, which should be carefully chosen, bearing in mind the height range involved and the nature of the country. Allow 100 feet, or some such exact figure, to each horizontal line on the graph-paper, for ease of plotting. Number the vertical scale at suitable intervals, avoiding columns of noughts. Unless the horizontal scale is large and the range of altitudes considerable, the vertical scale must be considerably larger than the horizontal, otherwise the undulations along the profile will hardly be perceptible. On the other hand, too large a vertical scale will produce a ridiculously caricatured effect of the land surface. This relation between the horizontal and vertical scales is known as the *vertical exaggeration*. Thus if the horizontal scale is 1 inch to 1 mile (i.e. R.F. 1:63,360) and the vertical scale is 1 inch to 1,000 feet (i.e. 1:12,000), the exaggeration will be 5·28 times. Always state the exaggeration below the profile. No exaggeration should be used for accurate geological sections (see p. 110), which would otherwise give an inaccurate dip to the strata. Either by following the vertical graph-lines, or by ruling perpendiculars from the ticks on the base-line, mark the position of each point according to the vertical scale, with a fine accurate cross. When all points are plotted, join them by a smooth line, not by a series of straight lines. To interpret the detail between two widely spaced contours, use any other indications of the relief, such as spot-heights near the line of profile, the position of streams, and information from hachures. It may even be necessary, if profiles are being used for advanced land-form study, to level accurately each line of profile in the field, especially when the contour-interval of the map is considerable. When drawing in the profile, care must be taken (*a*) to start from the exact height at either end; (*b*) to distinguish between dips and rises where there are two successive contours numbered identically; and (*c*) to draw carefully the outlines of summits, whether peaked or flattened.

Finish off the line-work in ink, add significant place-names, lettered in sideways above the point on the section to which they refer, together with a title, and give the grid reference of either end. Unless a location-map is included, indicating the plan of the profile, specify also the orientation. If the profile is originally drawn on graph-paper for convenience, it may be traced on to drawing-paper, omitting the horizontal graph-lines.

Serial Profiles

A series of profiles, to illustrate the edge of a plateau[1] or the transverse shape of a valley from the source of a river to its mouth,[2] or the character of a coastline, may be drawn with effect. They can be arranged in a vertical column, representing for example a series from north to south, accompanied by a location map.

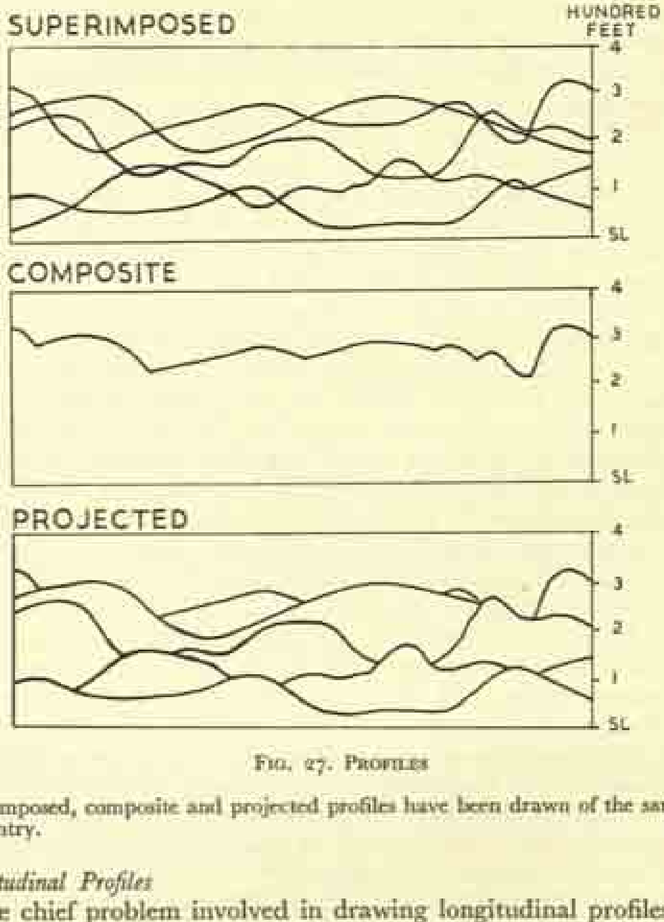


FIG. 27. PROFILES

Superimposed, composite and projected profiles have been drawn of the same piece of country.

Longitudinal Profiles

The chief problem involved in drawing longitudinal profiles is the transference of points along a curved or winding road, railway or river to the straight-edge which forms the base of the profile. The distance between each contour, spot-height or other feature must be accurately

[1] F. J. Monkhouse, *The Belgian Kempenland*, p. 24 (Liverpool, 1948).

[2] M. Jones, 'The Development of the Teifi Drainage System', *Geography*, vol. 34 (London, 1949).

determined by stepping it off with dividers, and then ticking it off along the straight-edge. Railway profiles are difficult to draw, since 'cutting and filling', i.e. the grading of the track by cuttings and embankments, may have removed or smoothed out minor changes of slope, and contours often end abruptly at the edge of the cutting symbol. Railway profiles as a rule can only be accurately drawn when a large-scale map is available, showing numerous spot-heights along the track itself. Information can be obtained from official track-descriptions, or the actual gradients can be read from the gradient posts along the track.

Superimposed Profiles

It is a useful practice to compare and to correlate profiles spaced at regular intervals across a piece of country, and then to plot them on a single frame.[1] Each individual line should be carefully numbered and located on an accompanying map. These are known as superimposed profiles (Fig. 27, top). Unless, however, the landforms have some morphological unity, such as an erosion platform, which will be shown up by the general uniformity of level of the various profiles, the result is apt to look somewhat muddled, and the several profiles should then be placed separately. Alternatively, the base can be raised, as is done for the beach-profiles shown on Fig. 28. E. H. Brown plotted the profiles of a series of valley-spurs, in order to bring out breaks of slope which might not be apparent in the valley-sides. He drew a profile along the crest-line of each spur, 'pulling-out' each profile into a straight-line. The spur-profiles were then plotted on a single diagram, but for clarity each was 'staggered', and lowered in relation to the preceding one.[2]

Composite Profiles

A composite profile is constructed to represent the surface of any area of relief, as viewed in the horizontal plane of the summit-levels from an infinite distance, and so including only the highest parts of a series of parallel profiles (Fig. 27, middle). A number of closely spaced equidistant parallel lines is ruled across the area; the orientation of these lines should be carefully chosen; in the Highlands of Scotland they might run from north-west to south-east, i.e. transverse to the 'grain' of the country. Place a straight-edge of paper along the

[1] There are numerous examples of superimposed profiles as applied to geomorphological problems. J. W. Wright, 'The White Nile Flood Plain and the Effect of Proposed Control Schemes', *Geographical Journal*, vol. 114 (London, 1949), has two series of superimposed bank-profiles; C. A. M. King and W. W. Williams, 'The Formation and Movement of Sand Bars by Wave Action', *Geographical Journal*, vol. 113 (London, 1949), have two series of superimposed beach-profiles, representing the same beach at successive dates.

[2] E. H. Brown, 'Erosion Surfaces in North Cardiganshire', *Transactions and Papers, 1950: The Institute of British Geographers*, no. 16 (London, 1952).

outside parallel line, with a set-square at right-angles to it. Slide the set-square along the straight edge, reading off the highest point, on whichever parallel line it occurs, and noting it on the straight-edge. Transfer these points to a base-line on graph-paper, plot them and join them with a smooth line, as for an ordinary profile. A lengthier method is to draw a profile along each parallel line, super-impose each in pencil, and join up all summit lines.

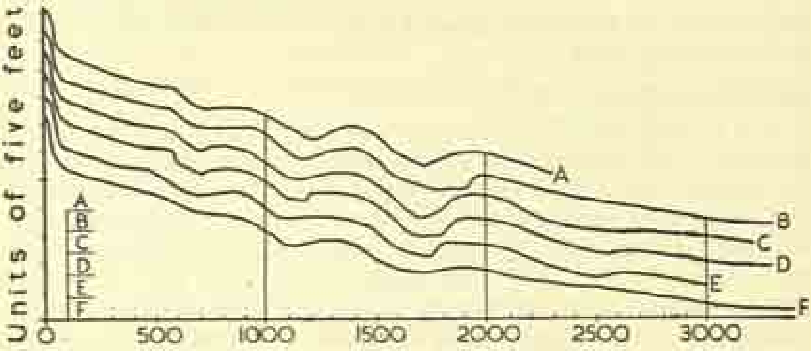


FIG. 28. TRANSVERSE BEACH-PROFILES

Compiled by R. K. Gresswell, from data personally surveyed on Southport beach. The datum for each profile was fixed at 10 feet below O.D. The letters refer to successive dates, viz. **A.** 21 Oct., 1935; **B.** 3 Jan., 1936; **C.** 5 March, 1936; **D.** 13 May, 1936; **E.** 25 July, 1936; and **F.** 28 Oct., 1936. The profiles have been placed in series, each with a different base, in order to avoid confusion, and yet to facilitate ready comparison.

Projected Profiles

It is possible to plot on a single diagram a series of profiles, including only those features not obscured by higher intervening forms. This will give a panoramic effect, with a distant sky-line, a middle-ground and a fore-ground; it is, in fact, an outline landscape drawing showing only summit detail (Fig. 27, bottom). The profiles should be spaced at equal intervals, but it is possible to add selected lines, running along, for example, a crest-line.[1]

[1] Three examples from the many available will suffice:

(*a*) J. Barrell, 'The Piedmont Terraces of the Northern Appalachians', *American Journal of Science* (4th series), vol. 49 (New Haven, Conn., 1920).

(*b*) A. A. Miller, 'The Entrenched Meanders of the Herefordshire Wye', *Geographical Journal*, vol. 85 (London, 1935).

(*c*) D. L. Linton, 'Some Scottish River-Captures Re-examined', *Scottish Geographical Magazine*, vol. 67, p. 36 (Edinburgh, 1951), uses a double projected profile of the Tilt through-valley in the Grampians in a most effective manner. He projected the heights of the bordering hills and valley walls as depicted on the One-inch map "from each side on to a composite line made up of straight lengths following the centre of the valley", and drew two projected profiles, one on either side of a central line on which distances in miles and true bearings in degrees were marked.

Reconstructed Profiles

It is sometimes useful in the elucidation of geomorphological problems to reconstruct a pre-existing profile. This is especially important in the examination of the effects of rejuvenation of a drainage system on the present form of a valley, when it is necessary to reconstruct the original profile below the knick-point clearly visible on the present profile. The latter is first drawn; obviously it is tempting to prolong by eye the curve of the upper course, but this would be most unsatisfactory. Various formulae have been devised, involving the height of the source, length of stream, the distance of any point from the mouth, and certain constants determined by trial.[1] Using such a formula, a number of points can be plotted and the lower portion below the knick-point reconstructed.

Gradient and Slope

The Significance of Slope Determination

The topographical map presents much precise information, "but it has had the effect of elevating simple height to an unmerited eminence".[2] The geographer is concerned with many other features of the landscape, particularly the slope (its amount and changes), the mean height, surface-levels and platforms, 'breaks' and 'edges', and the like. The exact height of a point above sea-level is for some purposes much less important than the relation of its altitude to that of surrounding areas. Some of these considerations have been discussed already when dealing with profiles.

The analysis of slope and its representation on a map has been the subject of much research, particularly by American geomorphologists. The calculation of average gradient, either along the steepest slope (i.e. at right-angles to the contours) or along a road, is a simple matter. But to work out some representation of *average* slope, particularly in an area of complicated relief, and to express this on a map to provide a clear picture which may help the geomorphologist to make important deductions, is a much more complicated affair. The analysis of average slope may be quite objective and arbitrary, using methods of random sampling or of uniform grids as bases for calculations of each unit area.

[1] O. T. Jones, 'The Upper Towey Drainage System', *Quarterly Journal of the Geological Society*, vol. 80 (London, 1924).
F. N. Green, 'The River Mole', *Proceedings of the Geologists' Association*, vol. 45 (London, 1934).
A. A. Miller, 'Attainable Standards of Accuracy in the Determination of Pre-Glacial Sea-Levels by Physiographic Methods', *Journal of Geomorphology*, vol. 4 (New York, 1941).
R. F. Peel, 'The North Tyne Valley', *Geographical Journal*, vol. 98 (London, 1941).

[2] A. A. Miller, 'The Dissection and Analysis of Maps', Presidential Address, 1948 to the *Institute of British Geographers*, published in *Transactions of the Institute*, Publication No. 14, p. 3 (London, 1949).

A geomorphologist examining a specific problem, such as the slope of an erosion platform, may well choose to omit valleys produced in this platform by subsequent erosion, which may have steep sides and so would profoundly affect the figure for the whole area computed by an arbitrary method. He wishes to find the slope of the original platform and so omits the irrelevant slopes; this is analogous to the generalized contours discussed on p. 58. Moreover, the difference in value between the arbitrary and the selective figures is in itself an index of the amount of subsequent dissection, which can in fact be used as a comparison with other morphological areas.

The Calculation of Gradient

It is sometimes essential to be able to express exactly the steepness of a uniform slope. If two points on a hill-side are projected on to a horizontal plane, as they are on a map, the distance between them is known as the *Horizontal Equivalent* (H.E.). The difference in vertical height between the two points is known as the *Vertical Interval* (V.I.). The gradient is expressed as a proportion, V.I./H.E., with the V.I. reduced to unity. Thus if the H.E. is 500 yards, and the V.I. is 150 feet, the gradient will be 150/1,500, or one in ten.

The gradient may be expressed as an angular measurement between the horizontal plane and the line of slope. This can be given approximately by multiplying the gradient, expressed as a fraction, by 60, which is reasonably correct to a slope of about 7°.

Thus, a slope of 1°=*gradient of* 1 *in* 60 (*actually* 57·14)
a slope of 2°=*gradient of* 1 *in* 30 (*actually* 28·65)
a slope of 3°=*gradient of* 1 *in* 20 (*actually* 19·08)

The slope in degrees can be accurately computed by expressing the gradient as a fraction, reducing it to a decimal, and then looking the angle up in a table of tangents, for the tangent of the angle of slope equals V.I./H.E. This can obviously be used, given an angle of slope (obtained, for example, by a clinometer) to find the H.E. for a given contour interval, or to find the V.I. for any given H.E.

To obtain maximum slopes on a hill-side, the H.E. is measured as far as possible at right-angles to the contours. If an area has a uniform slope in a more or less constant direction, a series of equidistant lines drawn down the steepest slope will be more or less parallel. The slope is calculated along each line and the mean of the results obtained; this will give an indication of the average slope of the area as a whole. Where the land has slopes of differing degrees of steepness in various directions, it will be necessary to divide the map into areas of broadly similar slope, or 'facets', by inspection, and these units will be used

as bases for calculation. Facets with certain critical slopes may be distinguished and mapped; this would be necessary in, for example, a study of soil erosion, 'sheetwash', flood and run-off.[1]

If road gradients are required, the H.E. must be carefully measured along each bend (see p. 54). Spot-heights should be used rather than contour intersections, as far as possible. These road gradients can be very misleading, since on a small-scale map, at any rate, minor dips and rises are masked. The same caution should be noted when calculating gradients of railway tracks, as when drawing track-profiles (see p. 71). However, such calculations can be of practical value if a road-profile in hilly country is to be constructed; any striking gradients can be expressed precisely in figures on the profile, and thus give much practical information to a motorist or cyclist. This is the method employed by compilers of Road-books.

Scales of Slopes

A useful graphical exercise in connection with contour-maps is the construction of some form of line-scale of slopes. Examine the horizontal scale and the contour-interval of the map in question. If the V.I. is 50 feet, then the H.E. will be 2,857 feet on the ground for a slope of 1° (as worked out from tangent tables), 1,435 feet on the ground for a slope of 2°, 954 feet for a slope of 3°, and, for example, 187 feet for 15°. Draw a horizontal line, and mark off along it these and other horizontal equivalents according to the scale of the map. Thus, on a six-inch map, when the contour-interval is 50 feet, a length of 3·24 inches between two successive contours will represent a slope of 1°, and a line of 0·21 inch will represent a slope of 30°. Slopes can be determined immediately by stepping off the distance on the map between two successive contours, transferring this to the line-scale of slopes, and reading off the degrees of slope indicated.

Another simple way of constructing a scale of gradients is shown in Fig. 29. It may be explained as follows:

> *Suppose scale of map*=1:63,360,
> *Then for a slope of* 1 *in* 20 *an H.E. of* 1 *inch on the map* (*i.e.* 5,280 *feet on the ground*) *will be represented by a V.I. of* 264 *feet, because*
>
> $$\frac{V.I.}{H.E.}=\frac{1}{20}=\frac{264}{5280}$$
>
> *If a V.I. of* 264 *feet is represented by* 1 *inch on the map, then a V.I. of* 250 *feet will be represented by*
>
> $$\frac{1\times 250}{264}=0\cdot 947 \textit{ inch.}$$

[1] This was done by A. T. A. Learmonth, 'The Floods of 12th August, 1948, in South-east Scotland' (circulated in manuscript form, 1951). He produced a map of the Lammermuir Hills, on which facets with gradients of 1 in 2 or over and those with gradients of from 1 in 2 to 1 in 3 were differentiated.

Draw a horizontal line *AB* any convenient length, and divide it into twenty equal parts. Drop a perpendicular *BC*, 0·947 inch long, and join *AC*. Drop perpendiculars from the upper line to pass through each point on the lower line; the lengths of these perpendiculars serve as a scale of horizontal equivalents. Slopes between 1 in 1, and 1 in 20, are read from the base-line, using a contour-interval of 250 feet; those between 1 in 20, and 1 in 100, are read from the upper line, using a contour-interval of 50 feet.

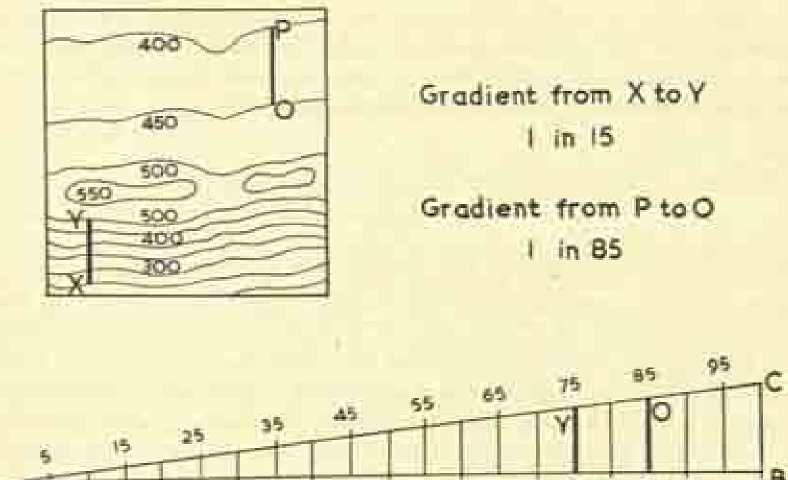


Fig. 29. A Scale of Gradients

The gradient of slope *XY* can be read off immediately from the lower scale-line **AB** as 1 in 15; the gradient of *OP* can be read off from the upper scale-line **AC** as 1 in 85.

For slopes steeper than 1 in 20, lay a straight-edge of paper as far as possible at right-angles across the contours of the slope to be measured, and mark the horizontal distance between any contour-interval of 250 feet; alternatively, dividers may be used to step off this distance. Move the straight-edge or the dividers along the base-line of the scale until the distance coincides with a perpendicular between *AB* and *AC*. The corresponding gradient can then be read off from the *AB* scale-line.

For slopes gentler than 1 in 20, lay a straight-edge of paper at right-angles across the contours of the slope to be measured, mark the horizontal distance between a contour-interval of 50 feet. In the same

way, determine the corresponding perpendicular, and read off the gradient along the *AC* scale-line. Obviously, the distance *BC* represents a V.I. of 50 feet instead of 250 feet, as in the previous case; the intervals along *AC* therefore represent gradients proportionally gentler (i.e. five times as gentle, as the V.I. is five times smaller).

Wentworth's Method of Average Slope Determination

A 'general and random' method of determining average slope over an area from a map was devised by C. K. Wentworth.[1] He covered the contour-map of the area with an east-west, north-south grid, then counted all contour crossings, and tabulated them, so determining the average numbers of contour crossings per mile. The procedure was repeated using an oblique grid over the same area, and the two results were averaged. He then applied the following formula:

$$\frac{\textit{Average number of contour crossings per mile} \times \textit{contour interval}}{3361 \ (\textit{constant})^{2}}$$

The result gave the average slope in terms of the tangent of the average angle of slope, which can be converted into degrees with tangent tables.

Smith's Method of Slope Analysis

It is often important to relate the altitude of the highest and lowest points in any particular area, that is, to ascertain *the amplitude of available relief*.[3] This problem has been examined by G. H. Smith,[4] who used the term 'relative relief' or 'local relief'. This type of relief analysis was developed mainly in Germany by such workers as N. Krebs, H. Schrepfer, V. Paschinger, H. Kallner and others, and was applied

[1] C. K. Wentworth, 'A Simplified Method of Determining the Average Slope of Land Surfaces', *American Journal of Science*, series 5, vol. 20 (New Haven, Conn., 1930). Besides explaining clearly his method and formulae, he describes the earlier methods, with references, of A. Penck, S. Finsterwalder and J. L. Rich, and discusses their limitations.

[2] The constant figure 3361 is derived from a formula which is explained fully by Wentworth; it is $5{,}280 \times 0{\cdot}6366$, which figure is the mean of all possible values of $\sin\theta$, where θ is the angle between the grid-lines and the contours.

[3] Available relief is defined by W. S. Glock, in 'Available Relief as a Factor of Control in the Profile of a Land-Form', *Journal of Geology*, vol. 40, p. 74 (Chicago, 1932), as "the vertical distance from an original fairly flat upland down to the initial grade of the streams".

[4] G. H. Smith, 'The Relative Relief of Ohio', *Geographical Review*, vol. 25 (New York, 1935). Smith gives a full bibliography of German, Polish and other workers who developed the method. Apart from the interesting technique he describes, it is useful to read his analysis of vegetation, land utilization, and settlement in relation to 'local relief'.

by K. H. Huggins to an analysis of the Highlands of Scotland.[1] G. H. Smith used the method to make an analysis of the surface of the state of Ohio; his paper may be summarized briefly to illustrate the principles involved. He took a contour-map of Ohio on a scale of 1:600,000 and divided it into rectangles of 5 minutes each of longitude and latitude, representing approximately 4·40 by 5·75 miles on the ground, but, of course, varying slightly between the north and south of the state. He then calculated the difference in height between the highest and lowest points in each rectangle, obtaining about 2,000 values, which were plotted in the centre of each square on the base-map. Isopleths to indicate areas having the same amplitude in absolute altitude (i.e. the same 'local relief') were interpolated for each 100 feet of difference. The map was then shaded in eight tints, to indicate areas with the same 'local relief'. Further information was obtained by measuring the area of each 'relief province' (i.e. from 0–100 feet, from 100–200 feet, and so on), and then expressing each area as a percentage of the total land area of Ohio (41,263 square miles).

The resulting map brings out most strikingly the areas of high relative relief in the south and east (the outlines of the Alleghany Plateau), and the areas of low relative relief in the north-west (the Maumee Plain and the area south of Lake Erie). Smith's method has been applied to an analysis of the relative relief of the Dorking area (Fig. 30).

One obvious shortcoming is that the map presents *amplitudes* of maximum relief differences, which may be either between two points on opposite ends of a diagonal of any square, or in the case of a perpendicular cliff, may have no horizontal equivalent at all. Smith suggested that squares with extreme points far apart should be subdivided, but this would destroy much of the symmetry of the map. Miller[2] put forward the elaboration that the difference in height between maximum and minimum points in each square might be divided by the respective horizontal equivalent, the values plotted, and isopleths drawn.

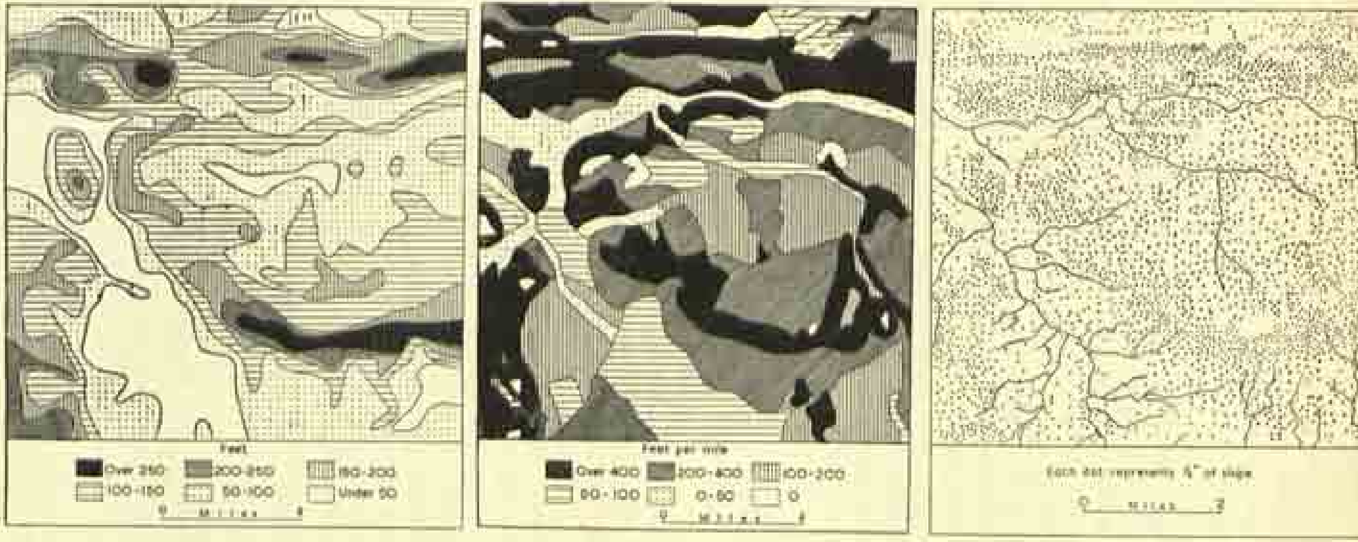
The Raisz and Henry Method of Average Slope Determination

Raisz and Henry[3] applied Smith's method of analysing 'relative

[1] K. H. Huggins, 'The Scottish Highlands: A Regional Study', *Scottish Geographical Magazine*, vol. 51 (Edinburgh, 1935). In an effort to delimit the Highlands, he used the grid of 2 mile squares which is superimposed on the One-inch O.S. Series (Popular Edition), and blackened in all squares in which the difference in height between the highest and lowest squares exceeded 700 feet.

[2] A. A. Miller, p. 8, *op. cit.*

[3] E. Raisz and J. Henry, 'An Average Slope Map of Southern New England', *Geographical Review*, vol. 27 (New York, 1937).



FIGS. 30–32. THREE METHODS OF SLOPE REPRESENTATION

Each map was compiled from data extracted from sheet 51/14, 1:25,000 series, Ordnance Survey. In the north is the line of the North Downs, in the west the Holmbury valley, and in the south-centre is Leith Hill.

Fig. 30 (left) was drawn using G. H. Smith's method, Fig. 31 (centre) using the method devised by E. Raisz and J. Henry, and Fig. 32 (right) using A. H. Robinson's method.

relief' to New England, but concluded that the results were not satisfactory in this particular case. Here the narrow valleys cut deeply into the peneplain and so give a big relief amplitude, as do isolated knolls projecting steeply from level surfaces. The relative relief figures for most of the area, therefore, are high, and mask important features. Raisz and Henry concluded that "[. . .] the method applied by Smith is good only on maturely dissected plateaux of horizontal sedimentary rock structure with uniform slopes and a simple physiographic history. In geologically complex regions, different methods must be applied." They then tried to bring out the detailed differences which were lost in Smith's large 5-minute rectangles by covering the state with a grid of mile squares, but the result was "a complex patchwork", unreproducable on a small-scale map of the whole state.

Their next refinement was to divide the topographical map, not into equal rectangles, but into irregular areas with some physiographic identity—monadnocks, incised valleys and so on. But the unequal areas proved unsatisfactory; thus an extensive though gently sloping plain might have a higher relative relief value than a monadnock of small extent.

Finally, Raisz and Henry divided the large-scale topographical map into small regions, within each of which the contour-lines had the same standard spacing, i.e. the same number of contour-lines per mile of horizontal equivalent. The chosen categories were six in number, representing slopes of under 50 feet per mile, 50 to 100 feet, at each intermediate 100-foot interval to 500 feet, and above that figure. A horizontal scale of standard contour-spacings was drawn, so that the number of contours per mile on the map-scale could be checked off with dividers, and the slope category ascertained by careful inspection. When the six categories had been demarcated on the large-scale maps, their boundaries were transferred to the small-scale state map, and tinted in six shades. The southern part of the map is reproduced in the reference cited above.[1]

The student should try this method, using a One-inch or a 1:25,000 Ordnance Survey map of an area of not too diversified relief. This

[1] Two applications of this method may be cited:

(a) R. B. Batchelder applied the methods both of Smith and of Raisz and Henry to an identical area, comparing the results, in 'Application of Two Relative Relief Techniques to an area of Diverse Landform: A Comparative Study', *Surveying and Mapping*, vol. 10 (Washington, 1950). The area chosen extended from Puget's Sound eastwards across the Cascade Range to the Columbia Plateau. He claimed that for this particular area Smith's method emphasized major landforms—their extent, continuity and inter-relationships. The method devised by Raisz and Henry represented secondary features in greater detail, but tended to obscure major relationships.

(b) G. B. Cressey, 'The Land Forms of Chekiang, China', *Annals of the Association of American Geographers*, vol. 28 (Lancaster, Pa., 1938), analysed from the 118 maps of the Chinese General Staff series, 1:100,000, with the aid of 2,500 miles of field

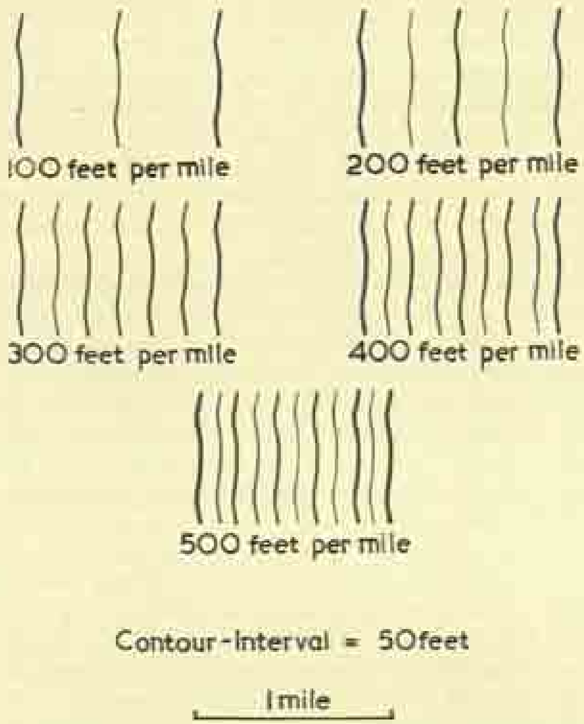


FIG. 33. A CONTOUR-SCALE OF SLOPES

A graphical scale of slopes can be constructed to assist in the division of a contour-map into series of units, each of which falls within a selected slope-category, as indicated by the spacing of the contours. Dividers can be set to a specific width (e.g. one inch), placed on the map, the contours within their span counted, and the slope-category determined by inspection from the contour-scale.

---

reconnaissance, a quantitative study of surface configuration in terms of slopes. He distinguished the following five categories:

	Spacing of Contours at 50 metres interval	*Slope*
(i) Coastal Flatlands	None	Flat, 0 to 2°
(ii) Interior Lowlands	More than 5 mm. apart	1° to 5° (1 in 100 to 1 in 10)
(iii) Rolling Hills	2–6 mm. apart	4° to 10° (1 in 12 to 1 in 4)
(iv) Mountainlands	1–2 mm. apart	10° to 25° (1 in 4 to 1 in 2)
(v) Steeplands	1 mm. or less	20° and over (1 in 2 and steeper)

The resultant data were plotted on a base map on a scale of 1:400,000 and reproduced as a folded map in the *Annals*, with five grades of shading.

has been done in Fig. 31, using the same area (the neighbourhood of Dorking) as was selected for Fig. 30. The map was first carefully examined, and areas which seemed to have more or less the same density of contours were demarcated on superimposed tracing-paper; a contour-scale, similar to the one shown on Fig. 33, proved helpful. Then the map was worked over in more detail, and the boundaries of the areas were modified where necessary. Finally, the slope categories were chosen, a system of density shading was selected, and the various regions were tinted accordingly. Obviously, the arduous and critical part of this method was the delimitation of the areas, and much depended upon individual judgment.

Coefficient of Land Slope. Raisz developed a method of establishing an exact 'coefficient of land slope', a process which, however, is laborious in the extreme.[1] The map is covered with rectangles of some reasonable size; the more uniform the slopes the larger they can be. Each rectangle is divided into areas within each of which the slope is uniform (under 100 feet per mile, 100 to 200 feet per mile, and so on) by counting contours as described above for average slope-maps. Then the area of each category is measured with a planimeter. A line is drawn proportional in length to the total area of the rectangle, and the areas plotted to scale for each category as points along this line, with the zero on the left. Next a series of lines is drawn, each at the angle of slope corresponding to a vertical rise of 100 feet, 200 feet, and so on, to the maximum per mile; on Fig. 34 the maximum slope is 500 feet per mile. Each change of slope occurs perpendicularly above the point on the horizontal scale representing that particular contour. The area of the plane figure *XYZ* provides a coefficient of slope for the rectangle for which it has been drawn. This is calculated by finding through simple geometry the area of each plane quadrilateral enclosed by the two adjacent perpendiculars, the horizontal line and the line of the angle of slope, each of which is measured graphically, and then by adding the five results. Obviously, completely flat land will have a coefficient of zero. When the coefficient has been established for every rectangle on the map, plot each value at the geometrical centre of each rectangle, and draw isopleths through points with the same coefficient, or interpolate between them in the usual way.

Robinson's Method of Slope Analysis

A method was devised by A. H. Robinson[2] to produce a quantitatively accurate relief map from areal slope data. He covered his map with a network of squares each 0·01 square miles in area. The average slope

[1] E. Raisz, *General Cartography*, p. 278 (2nd edition, New York, 1948).

[2] A. H. Robinson, 'A Method for Producing Shaded Relief from Areal Slope Data', *Surveying and Mapping*, vol. 8 (Washington, 1948).

of each square was estimated, and one dot for each degree of average slope was placed within it. The dots were not placed symmetrically within each square, but their positions were determined by reference to the contours on the topographical map and to the dots in adjacent squares to produce some appearance of continuity. In theory, therefore, the dots are countable, so as to give precise information, and at the same time their density appearance gives a good visual impression.

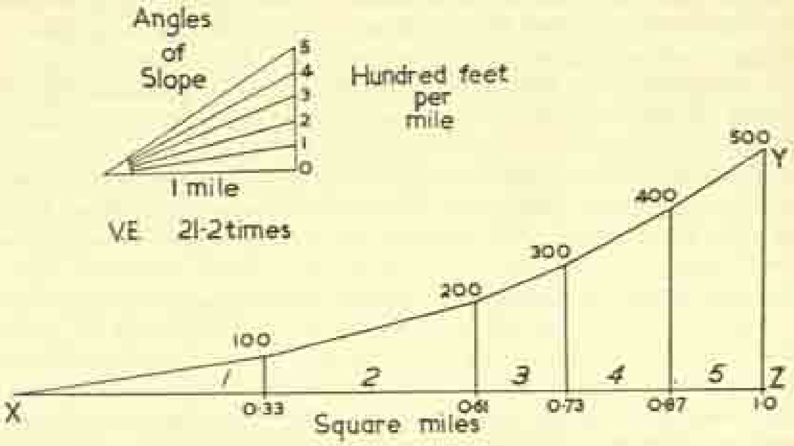


FIG. 34. THE COEFFICIENT OF LAND SLOPE

The area of the plane figure *XYZ* provides a coefficient of slope for that portion of the map (arbitrarily selected as a rectangle) for which it has been drawn. The upper diagram provides a convenient scale of angles of slope corresponding to 100 feet, and each succeeding 100 feet, up to 500 feet per mile.

The size of the dot must be carefully chosen, in order to produce effective visual contrasts of light and shade. The chief problem is, of course, to estimate the average slope of each square. Obviously, as Robinson points out, the most accurate method is by levelling in the field, following a traverse across the line of average slope. He quotes a complicated formula produced by J. A. Barnes, from which a table was prepared, enabling the computer to count the number of contours in each square, read off an average angle of slope, and therefore determine the number of dots.

The student should try the effect of this dot method, without necessarily going into details of slope calculation by elaborate formulae. Examine each square, estimate by an inspection of the contours the average gradient of the square, and convert this into degrees of slope (see p. 74).

This method has been carried out (Fig. 32), using the same region as for the two previous methods. The scale of the base-map was 1:25,000, and one dot was used for each half degree.

Other Methods of Slope Analysis

Further refinements concerned with the slope of the land can be developed. Any particular slope can be calculated for each square on a gridded map and isopleths drawn. For example, what Raisz[1] calls *flatland-ratio* maps can be constructed by calculating the percentage of each square occupied by land *below* any given crucial slope, plotting these values, and then drawing isopleths. If a ratio map is thought to be unnecessary, an *absolute flatland map* can easily be drawn by outlining all areas with slopes below any critical figure, and then shading them.

There is another elaborate method in which pictorial symbols of hills in profile are used; their heights are made proportional to the relative relief figure, their bases to the average slope. These symbols are distributed over the map, and in the case of a country with a strongly marked relief they give quite a vivid impression.

Slopes may also be indicated simply on land-use maps by pecked lines (marking change of slope) and arrows (giving direction of slope). R. M. Glendinning,[2] for example, superimposes these slope symbols on a map, on which are also shown by tinting the effects of soil erosion and by index figures the grades of land use. A figure representing the slope in degrees can be placed beside the arrow; this is analogous to information concerning the dip of the strata on a geological map.

In a case where slope-categories have been determined, further useful information can be derived by measuring the area of each category, and then expressing it as a percentage of the total area. This can be done for areas with some physical unity, such as a river basin. If a series of graphs is drawn, the results may produce some striking data to assist in an analysis of catchment areas, run-off, flood regimes and the like (Fig. 35).

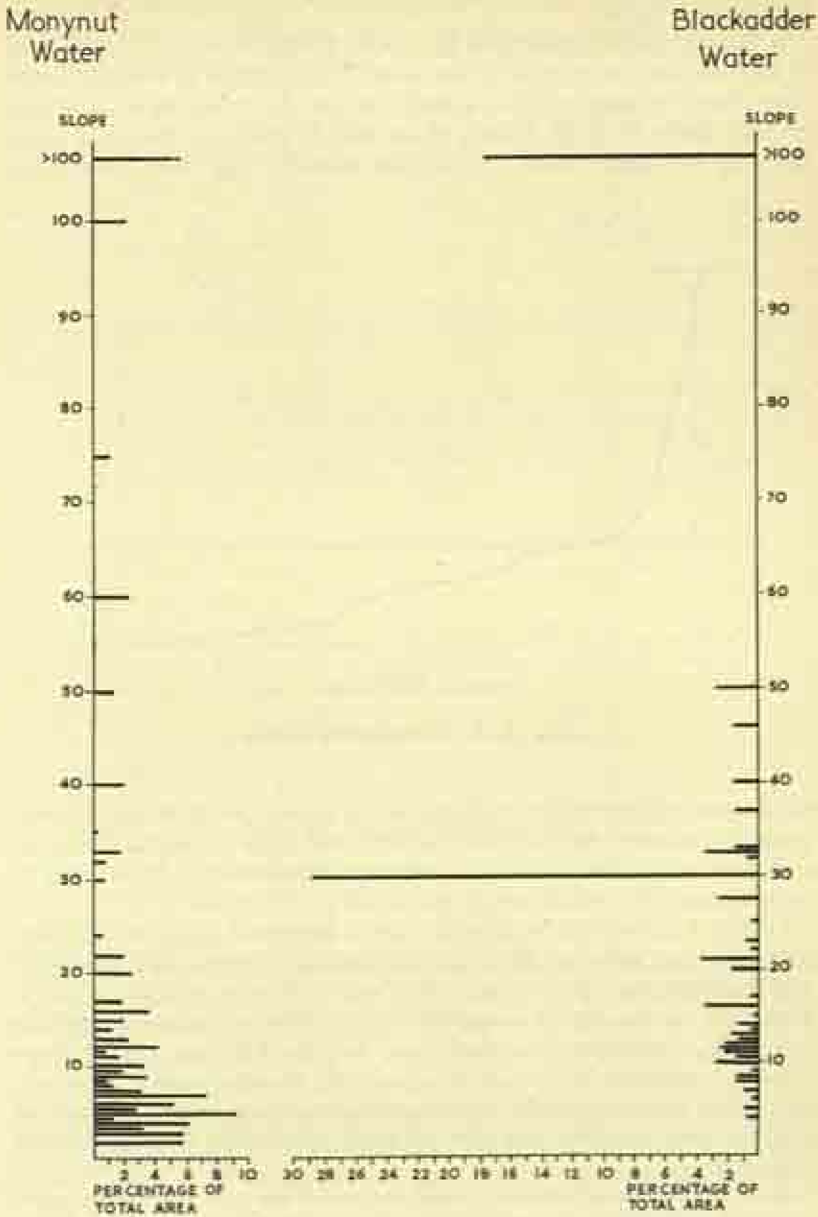
[1] E. Raisz, *General Cartography* (2nd edition, New York, 1948).

[2] R. M. Glendinning, 'The Slope and Slope-Direction Map', *Michigan Papers in Geography*, vol. 7 (Ann Arbor, Mich., 1937).

FIG. 35. COLUMNAR DIAGRAM OF SLOPES

Compiled by A. T. A. Learmonth, in 'The Floods of 12th August, 1948, in South-east Scotland' (circulated in manuscript form, 1951).

The bars represent the percentage of the total catchment area of the Monynut and Blackadder (tributaries of the Tweed) at a certain slope (1 in 10, 1 in 20, etc., as shown on the verticale scale), and so enable the configuration of the two river basins to be compared at a glance.



Monynut Water
Blackadder Water
SLOPE
>100
100
90
80
70
60
50
40
30
20
10
2 4 6 8 10
PERCENTAGE OF TOTAL AREA
30 28 26 24 22 20 18 16 14 12 10 8 6 4 2
PERCENTAGE OF TOTAL AREA

Hypsographic Curves

A hypsographic (sometimes known as a hypsometric) curve is used to indicate the proportion of the area of the surface at various elevations above or depths below a given datum. If, for example, a hypsographic curve is to be drawn of an island, calculate the total area, the area enclosed within the 100-foot contour, and then those areas

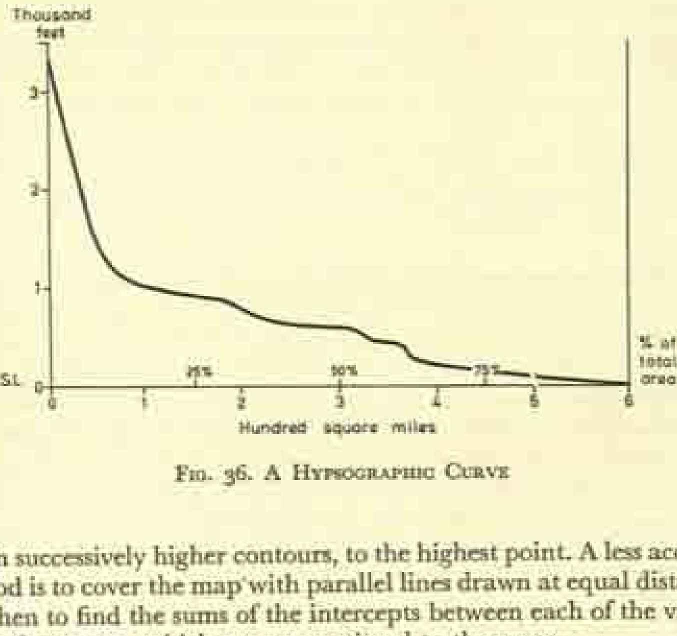


FIG. 36. A HYPSOGRAPHIC CURVE

within successively higher contours, to the highest point. A less accurate method is to cover the map with parallel lines drawn at equal distances, and then to find the sums of the intercepts between each of the various pairs of contours, which are proportional to the areas.

Choose a convenient horizontal scale to represent the areas in square miles, putting zero on the left. Alternatively, express this measured area between each particular pair of contours as a percentage of the total area of the region in question, and draw a horizontal percentage scale. Construct a vertical scale on the left side of the base-line to represent height above sea level, at appropriate intervals. Plot each area against its corresponding contour interval, mark its position with a cross, and join up each point with a smooth curve (Fig. 36).

The hypsographic curve should be used for an area with some physical unity, such as an island, which will bring out the relative area of coastal plain, plateau, and mountain range, or an erosion platform. For example, S. W. Wooldridge drew a series of hypsographic

curves for various parts of south-eastern England, calculated from the Ordnance Survey Half-inch series, which show clearly the 200-foot 'platform' or planation surface.[1]

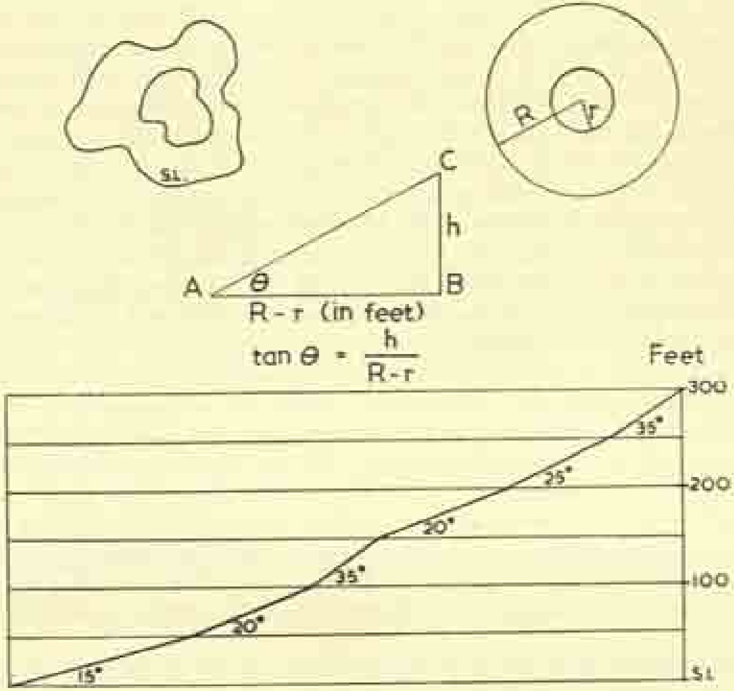


FIG. 37. A CLINOGRAPHIC CURVE

The contour-interval in this case is 50 feet.

Clinographic Curves

The clinographic curve seeks to illustrate the average gradient between any two contours, and to express a series of these averages in a single curve. Its chief value, therefore, is that it indicates both sudden changes and breaks in the general relief of any region, and moreover it emphasizes uniform areas such as plateaus. It gives at the same time average gradients, the percentage extent of each average gradient, and exact breaks of slope. It is much more sensitive to small changes than a hypsographic curve, and in some cases it is less misleading.

[1] S. W. Wooldridge, 'The 200-foot Platform in the London Basin', *Proceedings of the Geologists' Association*, vol. 39 (London, 1928), and reproduced in S. W. Wooldridge and R. S. Morgan, *The Physical Basis of Geography* (London, new impression, 1946).

The area of land between two successive contours is measured. If the area enclosed by the sea-level contour is represented by x square inches and the area between the sea-level and the 100 foot contours is y square inches, these areas can be represented by circles of equivalent area, with radii R and r, for $x=\pi R^2$ and $y=\pi r^2$. Find R and r in inches, and convert these values by the scale-factor into feet. If a right-angled triangle is drawn, with BC equal to the contour-interval (h) and the base AB representing the difference in length between the radii ($R-r$), the angle BAC (i.e. the angle of slope) can be calculated, using the tangent formula. Similarly the angle of slope between each succeeding pair of contours is calculated. A clinographic curve can then be drawn, using the contour-intervals as vertical components and inserting each section of average slope between each two contours with a protractor (Fig. 37). If the clinographic curve is of gentle slopes, a vertical exaggeration can be introduced, by increasing each angle by a constant factor.

It is useful to draw the hypsographic and clinographic curves on the same diagram for comparison; the former will show the area of land involved, the latter the actual slope, between each successive pair of contours. Hanson-Lowe illustrates this by superimposing the clinographic curve of the island of Jersey (with an exaggeration of ten times) and the hypsographic curve on the same diagram.[1] A very striking application of the value of comparative hypsographic and clinographic curves is shown by W. G. V. Balchin, who determined them for four sub-regions of north Cornwall and for the area as a whole.[2]

A different method was suggested by Professor F. Debenham.[3] He measured the actual length of each contour, using an opisometer, and plotted this on a horizontal scale against a vertical scale representing the height of each contour.

Altimetric Frequency Graphs

Another method of analysing relief, especially valuable when the geomorphologist is seeking to recognize and correlate erosion surfaces, is to compute the frequency of occurrence of heights above sea level, and then to graph this frequency. H. Baulig made considerable use of this method.[4] In some cases he merely counted spot-heights all over the map, in others he covered the map of the area upon which he

[1] J. Hanson-Lowe, 'The Clinographic Curve', *Geological Magazine*, vol. 72, pp. 180–4 (London, 1935).

[2] W. G. V. Balchin, 'The Erosion Surfaces of North Cornwall', *Geographical Journal*, vol. 90, p. 59 (London, 1937).

[3] F. Debenham, *Exercises in Cartography*, p. 60 (London, 1937).

[4] H. Baulig, 'Sur une Méthode Altimétrique d'Analyse Morphologique Appliquée à la Bretagne Péninsulaire', *Bulletin de l'Association de Géographes Français*, No. 10 (Paris,

was working with a grid of small squares and noted the highest point in each square, either from an actual spot-height or by estimation from the contour pattern if no spot-height fell in a particular square. The frequency of occurrence of each height or group of heights

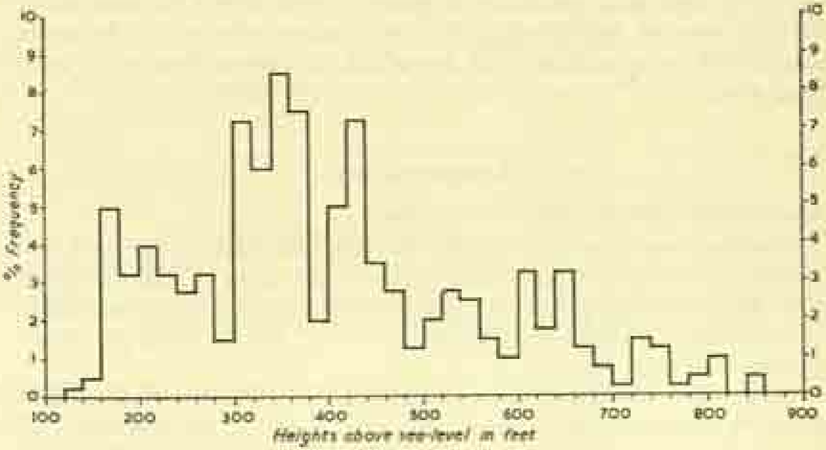


FIG. 38. AN ALTIMETRIC FREQUENCY GRAPH

Compiled from data extracted from sheet 51/14, 1:25,000 series, Ordnance Survey, representing the district south of Dorking, including the North Downs and Leith Hill. (Compare Figs. 30–2, which cover the same area.)

(e.g. from 20 to 30 feet) was tabulated, and these frequencies were graphed on a vertical scale against the actual altitudes represented on a horizontal scale. S. E. Hollingworth used the same principle with minor modifications.[1] Instead of using all spot-heights, he was concerned

1926); in this paper, he included altimetric frequency curves for the Armorican Massif as a whole and for the north and south zones, as well as for Léon, La Vendée and the Paris Basin.

Baulig's other works in which he includes examples of this technique are *Le Plateau Central de la France et sa Bordure méditerranéenne* (Paris, 1928), and 'The Changing Sea-Level', *Publication No. 3 of the Institute of British Geographers* (London, 1933).

[1] S. E. Hollingworth, 'The Recognition and Correlation of High-Level Erosion Surfaces in Britain: A Statistical Study', *Quarterly Journal of the Geological Society*, vol. 94 (London, 1938). He reproduces altimetric frequency curves for Devon and Cornwall, the Lake District, South-west Scotland, the Cheviots, North-west Wales, and South-west Wales. On Plate XI he puts all these curves on a single chart, graphing the number of actual summit-heights falling within each fifty-foot group. Especially valuable is his Fig. 3 (p. 62), on which he compares two altimetric frequency curves of Cornwall and Devon, one representing the number of summits in a 40-foot grouping by a line-curve, the other the number of summits in each 20-foot group represented by a histogram. In addition, he included a series of projected profiles of the same region drawn on the same vertical scale.

only with actual summit-levels, and he tabulated for each of the areas with which he was concerned the number of summit-level spot-heights occurring within 10, 20, 40 and 50-foot intervals. Obviously the broader groupings smoothed out minor inequalities, but emphasized the major features.

Fig. 38 depicts an altimetric frequency graph drawn for part of the Dorking area of Surrey, using Baulig's method of a grid; this covers exactly the same area as that for which the three Figs. 30–2 were produced.

Intervisibility

Intervisibility Exercises from Contour-Maps

Gradients are also involved in the determination either of intervisibility between two points, or of the whole area of 'dead-ground' from any particular position. There is a number of methods of solving intervisibility between two points, three of which may be briefly summarized (Fig. 39).

In the first method, draw a cross-section and rule a line of sight from the point of observation to the other point; if the line clears all intervening rises, the points are visible from each other. It is not necessary to draw a complete section; perpendiculars to scale representing any possible intervening eminences are sufficient. It must be remembered that minor irregularities not revealed by the contour-interval, as well as woods and hedgerows, may have to be allowed for.

A second method is to calculate the overall gradient of the line of sight from the observer to the second point, and also the gradients from any possible points of interference of view to the second point. Clearly, if the gradient of the line of sight to the far point is gentler than the gradients to any intervening points, then the two stations are intervisible.

A third and more accurate method of determining intervisibility employs the principle of similar triangles. Estimate the altitude above Ordnance Datum of the two points, using the nearest contour or spot-height, and by subtraction find the difference in height; thus, if A is 740 feet and B is 650 feet (Fig. 39), then the difference is 90 feet. Draw a line parallel to the line of view, a convenient distance away, nine units in length, and mark off as in the diagram. Join each end of the line of sight to the opposite end of the parallel line; these lines will cross at X. From any point P along the line of sight which would seem to interrupt visibility, draw a line through X and produce it to meet the parallel line at P_1, then read off the height indicated on this line, which actually gives the height of the line of sight at the particular point. Obviously, if this height is greater than the height of P,

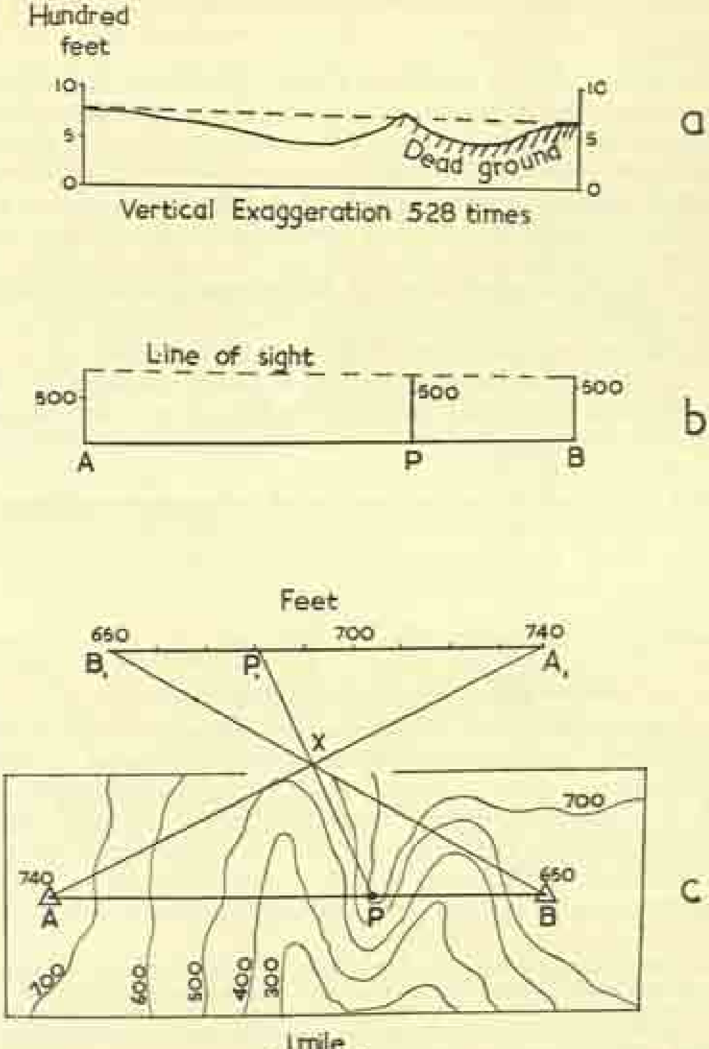


Fig. 39. Intervisibility

The methods illustrated use **a** a line of sight and a section, **b** a line of sight and perpendiculars from each possible interruption, and **c** the principle of similar triangles.

the line of sight will clear *P*, and the points will be intervisible.

Dead-Ground

Dead-ground may be plotted on a relief map with a fair degree of accuracy, but the reservations already noted as to the interruption of visibility by minor obstacles apply with equal force. Examine the map, noting all irregularities. Obviously, every point higher than the view-point will cause all the area beyond this to be dead-ground. In other cases, draw a profile and rule in a line of sight; this will show where the line reaches the ground beyond the intervening obstacle, and therefore the extent of dead-ground. Skirting profiles are necessary to find the side limits of dead-ground round each obstacle. Plot the edge of the dead-ground, and shade in the area thus delimited.

A useful method is to draw a series of radiating lines from the view-point. Examine the points at which the lines of view are obviously interrupted, and estimate their heights. By comparison with the height of the point of observation, it can be seen at what rate the line of view declines in altitude. Thus the height of the ray can be calculated at any point along it, and in fact the heights of the ray can be scaled along it. Where the ground-level as shown by the contours is below the height of the ray, the ground is 'dead'.[1]

Landscape Drawing and Field-Sketching

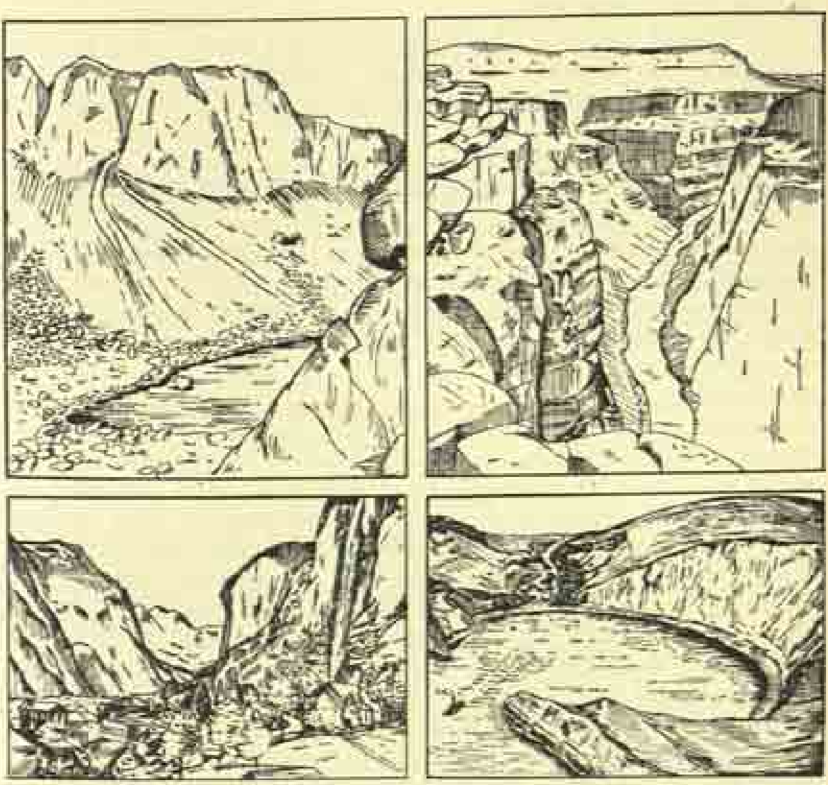
With the development of photography and of methods of reproducing photographs by half-tone blocks, landscape drawing has seemed to have lost much of its former importance. In the past, such geographers as G. K. Gilbert and W. M. Davis used simple yet most effective sketches to illustrate their concept of land-forms.[2] Recently, however, both in Britain and America, there has been an increasing tendency of geomorphologists to make use of clear bold sketches to help to clarify

[1] An application and elaboration of the general principle of plotting 'dead-ground' maps was devised by Dr. A. Garnett, 'Insolation, Topography and Settlement in the Alps', *Geographical Review*, vol. 25 (New York, 1935), and also in 'Insolation and Relief', Publication No. 5 of the *Institute of British Geographers* (London, 1937). She produced a series of maps showing (*a*) winter noonday shadow areas, (*b*) the periods of potential sunshine experienced at the equinoxes, and (*c*) the intensity of insolation at noon at the equinoxes. The last maps bear 'iso-intensity lines', which show the percentages of intensity of insolation of the maximum possible. The article describes fully how these maps were plotted. The maps are closely related to land utilization and settlement in a number of Alpine valleys.

[2] G. K. Gilbert, *Report on the Geology of the Henry Mountains (Utah)* (Washington, 1877), used field-sketches, closely associated with block-diagrams and geological sections, in a most graphic and revealing manner, as did W. M. Davis, *Geographical Essays* (Boston, 1910).

geomorphological problems.[1] These drawings show economy of line, and enable a geographer to select and emphasize salient features by omitting minor foreground and other irrelevant details.

A geographer should practise sketching in the field, to amplify and



FIGS. 40–3. LANDSCAPE SKETCHES

Fig. 40 depicts a corrie, with tarn, screes and crags (Dow Crag and Goats Water, near Coniston); Fig. 41 is of the Grand Canyon of Colorado; Fig. 42 is a U-shaped glaciated valley, with benches, cascades and alluvial cones (Lauterbrunnen); and Fig. 43 shows a cove formed by marine erosion (Lulworth Cove, in Dorset).

illustrate his maps and text. This will help the development of an eye for country, which is of first-rate importance, and will stimulate his powers of observation and appreciation. In addition, a student can

[1] See D. L. Linton, 'Watershed Breaching by Ice in Scotland', *Transactions and Papers, 1949*, the Institute of British Geographers (London, 1951); and R. F. Peel, 'A Study of Two Northumbrian Spillways', *ibid.*; the latter uses some half-dozen sketches of remarkable clarity.

illustrate essays concerned with land-forms by means of rapidly-drawn sketches. Figs. 40–3 show some examples of how simple sketches can be used to illustrate various topographical features.[1]

Sketches from Contour-Maps

It is a useful exercise in the interpretation of a contour-map to make a simple sketch of one's concept of the landscape as it would appear to an observer at some specific point. If the sketch is then compared with a photograph taken from the same point, or better still with the actual country, the results are sometimes very chastening. There are various geometrical methods available, one of which is described by D. Sylvester.[2] It is based on the projection of suitable points on a contour-map drawn within a cone, on to a plane surface placed at right-angles to the median line of the cone. These points must be chosen to delimit foreground, middle-ground and background hill profiles, and in addition 'water-lines' such as the coast and rivers, and any other essential detail. These points are then joined to form a line-drawing.

Another method is clearly demonstrated by Raisz.[3] Two lines are drawn radiating from the point of observation, enclosing an angle of about 45 degrees, to represent the field of view; these can either be ruled lightly in pencil on the actual contour-map, or on a sheet of superimposed tracing-paper. A horizontal line is then ruled across the map at right-angles to the line of sight of the observer. This line will be placed according to the size of the panorama required; obviously the nearer the line is placed to the viewpoint, the smaller will be the area of the landscape shown. Then a number of significant points, such as summit spot-heights, are projected on to this horizontal line by lines of sight from the point of observation drawn through the particular point on the map. This will locate the horizontal component of each point relative to the observer. The vertical component, which will enable each point to be fixed on the panorama, is then obtained, either by estimating a vertical scale which appears to give a reasonable impression of height (usually involving some exaggeration), or by means of a hyperbolic vertical scale. On such a scale, the base-line represents the height of the observer's horizon (i.e. it is at the same

[1] The geometrical relationship between the landscape, a photograph, a map, and a block-diagram or relief model is very clearly illustrated by E. Imhof, *Gelände und Karte*, p. 156 (Zürich, 1950). This example is reproduced in *Geographica Helvetica*, vol. 5, p. 301 (Bern, 1950).

[2] D. Sylvester, 'A Method of Panorama Construction from Contoured Maps', *Geography*, vol. 28 (London, 1943). This article fully explains the procedure, with examples.

[3] E. Raisz, *General Cartography* (New York, 1948).

height above sea-level as the point of observation), while the vertical scale decreases in inverse proportion to the distance from the point of observation.

Sketching in the Field

It is not necessary to have any artistic ability to be able to sketch in the field, for it is possible to employ various 'rule of thumb' principles. Use a sketching-block with stiff cardboard backing, an H pencil, and a ruler or service protractor. From the view-point, examine carefully the country to be depicted, note the sky-line profile, then the middle-ground detail, and finally the foreground. Decide on the extent of the panorama to be included; a horizon arc of about thirty degrees is usually sufficient.[1] Note any prominent point on the horizon about the centre of the area to be sketched, and draw a vertical line on the paper through it. Rule also a horizontal line across the middle of the paper, following if possible some definite line on the country. The sketch can then be drawn by eye alone; estimate the vertical and horizontal positions relative to the guide-lines of main features such as hill-tops, plot them on the paper, and then work from these to minor features. To obtain greater precision, fix the positions of important features relative to the guide-lines with a ruler, and mark them proportionally on the drawing. For greater exactness, but with more tedium, cut a hole in a piece of card the size of the intended sketch, covered with a piece of celluloid ruled with a grid.[2] This is held at a fixed distance from the eye, and detail is transferred, square by square, to the paper.

Often a disappointingly flat impression of country is given by a photograph; a landscape drawing must introduce a vertical exaggeration to appear natural. A twofold exaggeration is suitable, i.e. the height of a point from the bottom of the sketch should be increased twice compared with the horizontal measurement. This is especially necessary for a sketch of country viewed from a hill-top.

Once the framework of the sketch has been built up, detail can be easily added. The rules of perspective should be obeyed, to convey the impression of distance, and the scales of known objects such as trees and houses must be carefully observed. Detail should be simplified and to some extent symbolized: woods by a wavy outline, lightly

[1] *The War Office Manual of Map-Reading, Photo-Reading and Field-Sketching* (H.M.S.O., 1929) states (p. 73) that if a Service protractor is held eleven inches from the eye it will subtend an angle of 25°, i.e. it will obscure the country with a horizon arc of 25°. The protractor can be kept at a uniform distance by a piece of string 11 inches long, one end fastened to the protractor, the other held in the observer's teeth.

[2] E. Imhof, *Gelände und Karte*, p. 200 (Zürich, 1950), describes and illustrates an instrument known as a *Sitometer*, by which the angular distance relative to the observer of points in a panorama can be accurately measured.

stippled; clumps of trees in outline; rivers by a double line in perspective with light longitudinal shading; and villages by a few rectangles, with such elaborations as a church-tower and chimneys. Draw in the foreground detail by heavier lines, more distant detail by fine or even lightly pecked lines.

Annotation can add valuable information to a sketch.[1] Names and spot-heights can be placed above hills, and names of villages, lakes and so on lettered beside those particular features. Land utilization and anything else clearly visible may be indicated by capital letters or symbols. The sketch should be orientated by a note in the caption, as 'view from *X*, looking south-east', and an indication of scale by a statement: 'The distance between *A* and *B* is 3 miles.' Ink in the finished sketch, or make a new tracing in ink from the field-sketch.

Sketching from a Photograph

Often the only source of illustration for some theme is a poor photograph, indistinctly showing the desired feature; this will appear even worse on reproduction by means of a half-tone block. It may be far better to redraw the scene in ink for reproduction as a line-block. Place the photograph on a well-lighted tracing-table, with a piece of tracing-paper over it, and outline the main features in pencil, picking out the essential elements and omitting minor foreground detail, as is done in field-sketching. A small photograph can be covered with a grid, and the detail then transferred on a larger scale in the same manner as in map-enlarging (see p. 46). Ink in when the pencil sketch is completed, adding any desired annotation. Obviously no vertical exaggeration is involved, as mentioned above, and in some cases the result may appear flat. It is possible to shorten these processes by drawing in waterproof Indian ink directly on to the surface of a bromide print; details can be accurately followed. Then bleach away the photograph in a suitable medium,[2] and rephotograph the line-work.

Block-Diagrams

Block-diagrams are widely and effectively used to illustrate the features of the geomorphology of a particular area, or of specific land-forms. They are in effect sketches of relief models, rather than actual

[1] Griffith Taylor, 'British Columbia: A Study in Topographic Control', *Geographical Review*, vol. 32 (New York, 1942), includes a number of simple yet exceedingly clear and informative annotated sketches.

M. Hardy and A. Geddes, 'Lewis', *Scottish Geographical Magazine*, vol. 52 (Edinburgh, 1936), have an annotated 'diagrammatic view' in colour across the Isle of Lewis from south-west to north-east. Land utilization on the diagram was shown in colour, to correspond to an accompanying land utilization map.

[2] See *The British Journal Photographic Almanac, 1950*, p. 318 (London, 1950), for technical details.

pictures of sections of the earth's crust. They have the added advantage that geological sections can be appended to the sides of the block (see pp. 107–8), thus enabling correlations to be made between structure and surface (Figs. 51, 53). A series of such diagrams enable the stages of landscape development to be illustrated.

There are three main categories of block-diagram. These are, first, sketch block-diagrams of imaginary land-forms, drawn merely by eye or with the guidance of an outline of a simple geometrical figure; second, sketch block-diagrams drawn from a contour-map, not strictly in perspective, but giving the general appearance of a relief model viewed obliquely;[1] and third, block-diagrams, drawn from a contour-map, either with a one-point perspective, or with a two-point, or true, perspective.[2]

Sketch Block-Diagrams of Imaginary Land-Forms

For these block-diagrams it is best to begin with simple geometrical figures, such as cylinders or cones, as a basis; draw a vertical plan, next sketch a plan in one or two-point perspective, then the solid figure based on the ground-plan; this will afford accurate guide lines for the finished drawing. Thus a cone can be used as the basis for volcanoes, fans and mountains generally, or for a series of diagrams to show the growth of atolls by subsidence. Pyramids can be used for mountain peaks and mesas; portions of spheres or spheroids for cirques, drumlins and acid volcanoes; cylinders for fold mountains, glacial

[1] Professor F. Debenham, *Exercises in Cartography*, p. 78 (London, 1937), calls this "a pseudo-isometric projection of the contoured map".

[2] Most geomorphological text-books contain a wide variety of block-diagrams. The classic work is A. K. Lobeck, *Block Diagrams* (New York, 1924). G. K. Gilbert, in *Report on the Geology of the Henry Mountains (Utah)* (U.S. Geographical and Geological Survey of the Rocky Mountain Region, Washington, 1877), was probably the pioneer of their use. W. M. Davis used series of simple but extraordinarily effective block-diagrams in his many papers; see his *Geographical Essays* (Boston, 1910), and *Atlas for Practical Exercises in Physical Geography* (Boston, 1908). Other exponents are C. R. Longwell, A. Knopf, and R. F. Flint, *Outlines of Physical Geology* (New York, 1947); C. A. Cotton, *Geomorphology of New Zealand* (Wellington, 1926), and *Landscapes as Developed by Normal Processes of Erosion* (Wellington, 1948); C. Barrington Brown and F. Debenham, *Structure and Surface* (London, 1929); and E. de Martonne, *Traité de Géographie Physique* (Paris, 1926).

S. W. Wooldridge and R. S. Morgan make abundant use of simple sketch block-diagrams in *The Physical Basis of Geography* (London, latest edition, 1946).

F. Debenham, *Exercises in Cartography* (London, 1937), gives ten examples of the way in which block-diagrams of particular land-forms can be based on simple geometrical figures.

Block-diagrams, drawn accurately from large-scale contour-maps, can be used effectively for detailed regional studies. Two contrasting examples are the block-diagram of the Upper Teme Valley, in *The Land of Britain*, part 68, *Worcestershire*, Fig. 25, by K. M. Buchanan (London, 1944), and an annotated block-diagram, conveying a vast amount of information, of the San José Valley in California, compiled by E. N. Torbert, in 'The Specialized Commercial Agriculture of the Northern Santa Clara Valley', *Geographical Review*, vol. 26 (New York, 1936).

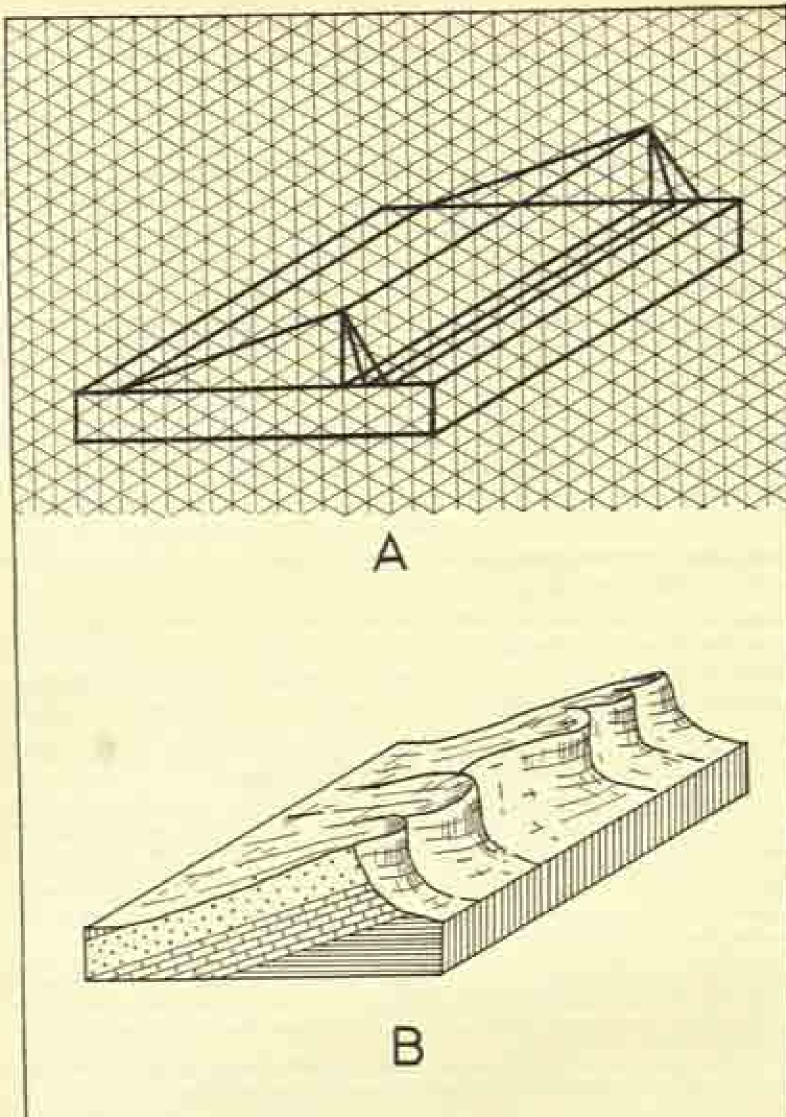


Fig. 44. An Isometric Block-Diagram

Isometric graph-paper provides ready guide lines for drawing geometrical figures upon which pseudo-perspective block-diagrams can be based.

valleys and fjords; and prismoidal blocks for cliffs, escarpments and ridges. A minimum of construction lines should be used. With experience, complex land-forms can be built-up by adding to or cutting out portions from one or more geometrical blocks. Isometric graph-paper can be used quickly and effectively to produce simple block-diagrams (Fig. 44).

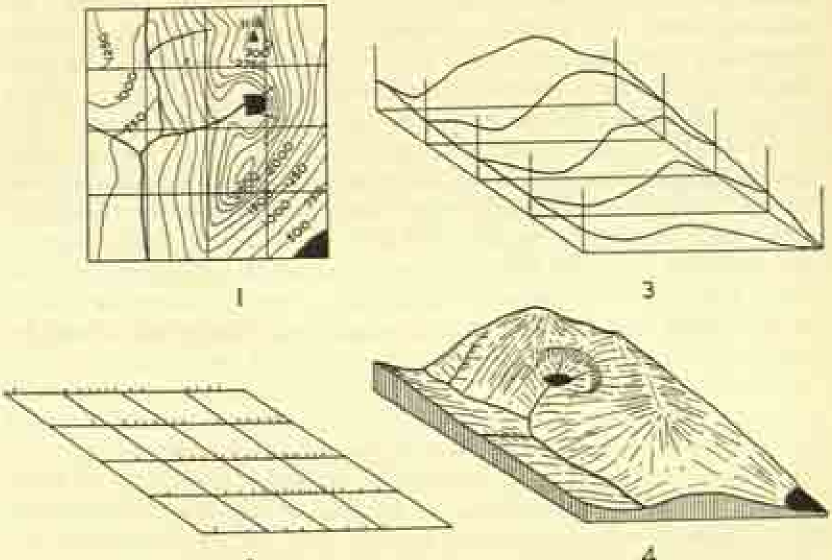


FIG. 45. THE CONSTRUCTION OF A BLOCK-DIAGRAM BY THE MULTIPLE SECTION METHOD

1. Contour tracing, with grid; 2. projection into a rhombus, and plotting of contour intersections; 3. construction of sections along the horizontal grid-lines; 4. completion of diagram with shading.

All this construction work is of course carried out in pencil. Ink in the edges of the block and the outlines of the relief, add light shading as in a perspective sketch to bring out slopes and minor details, and rule in vertical or horizontal shading to one or more sides of the block to give the impression of depth.

Block-Diagrams drawn from a Contour-Map

Trace a plan-view square from the contour-map of the desired area, showing only selected contours and streams, and cover the plan with a network of small squares. Examine carefully the contour-map, in order to determine the most satisfactory position from which the

observer may be assumed to be looking. Obviously a range of high hills along one side will be placed in the background, a U-shaped valley will be viewed more or less longitudinally, a cirque from a point opposite its mouth. When the orientation of the block-diagram has been decided, project the square and its grid into a rhombus;[1] the sides of the square and of the grid square will remain their true length (Fig. 46). The angle between the base and side clearly determines the obliquity of the block. This angle should generally lie between thirty and forty-five degrees; a higher angle will give the impression of a lofty view-point, a lower angle the converse. The relief details can now be transferred from the square to the rhombus, either by the multiple-section method or by the layer method.

The Multiple-Section Method (Fig. 45). Mark off contour intersections, spot-heights and summits, rivers and valleys, as for an ordinary section, by placing a series of straight-edges along each side of the block and along each line of the square grid in turn. Transfer these points to the projected rhombus. Choose a vertical scale; the exaggeration compared with the horizontal scale should not exceed ten times for a piece of level land, and in mountainous country no exaggeration may be necessary. Draw sections along the four edges of the block and along the horizontal grid lines. It is not necessary to draw every section; some may obviously lie in dead-ground, while others may be replaced by occasional perpendiculars. It may happen that certain conspicuous features are not adequately covered by the series of sections, so extra sections and perpendiculars may be inserted as required. Rivers, crest-lines, edges of escarpments and the like may be transferred directly from the ground-plan to the rhombus, and sections drawn along them.

Shade in the topography, using the sections, streams and other detail as guides, and carefully refer to the original map in order that minor details not shown by the sections will be accurately represented on the block. Take particular care over dead-ground. The representation of such features as lakes and tarns is difficult, for it is easy to make their surfaces appear sloping.

When the pencil draft is complete, ink in the edges of the block, the sky-line, the shading and other detail, and rub out construction lines. It may be easier and cleaner to retrace directly in ink, putting in only the required lines. Complete the block by shading the edge to give depth, add a title, a horizontal and a vertical scale, selected spot-heights, and any names of hills and streams. Put as much lettering as possible outside the block-diagram itself to avoid confusing the line-

[1] W. A. White, 'Topographic Sketches from Contour Maps', *Surveying and Mapping*, vol. 3, no. 4 (Washington, 1943), describes two methods of foreshortening contours from a contour-map before starting to construct a block-diagram. One method involves the use of photography, the other involves parallel projection, using a powerful beam of light as the projecting agent.

work. Rivers, lakes and their names can be inked in blue, spot-heights and hill-names in brown, railway lines in red and woods in green.

The Layer Method (Fig. 46). When the square and its grid have been projected into a rhombus, transfer on to it the contours and streams from the map, using the grid-lines as guides; this will produce a pseudo-perspective view of the contour-map. Choose a vertical scale, with

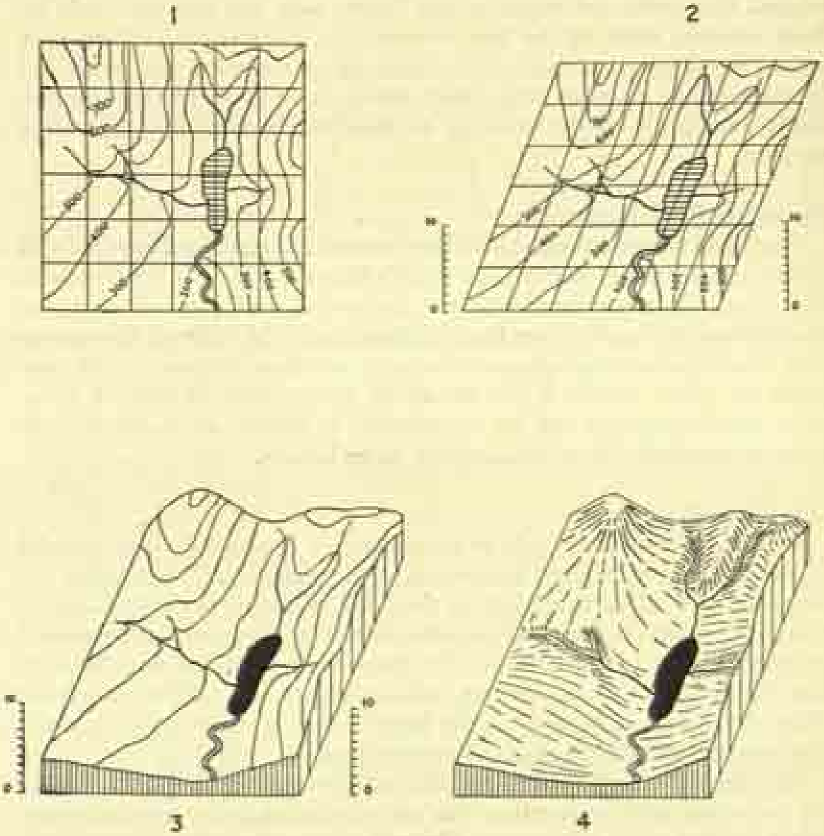


FIG. 46. THE CONSTRUCTION OF A BLOCK-DIAGRAM BY THE LAYER METHOD

1. Contour tracing, with grid; 2. projection into a rhombus, with vertical scale-lines (in hundreds of feet); 3. each contour is drawn in at its correct scale-altitude; 4. completion of diagram with shading.

some exaggeration if necessary. Draw on tracing-paper an outline of the rhombus, and drop perpendiculars at each corner of the base at the chosen scale, say, 0·1 inch to 100 feet. Place this tracing over the

pseudo-perspective plan, fitting exactly at the corners, then slide it up the vertical scale until the highest contour lies in the same plane as its height on the vertical scale, and trace in this contour. Slide down the tracing until the next highest contour lies opposite the same figure on the vertical scale and trace that in, and so on. If a lower contour cuts a higher there is no need to continue it, since it would obviously be out of sight.[1] Draw in streams and lakes at their correct height. Complete the edges of the block, join the contour ends by lines between each of the four corners, i.e. by sections, taking care not to insert any dead-ground. Then, using the contours, projected to their scaled heights, and other detail such as streams as guides, shade and finish off the drawing as described in the multiple-section method.

Perspective Block-Diagrams

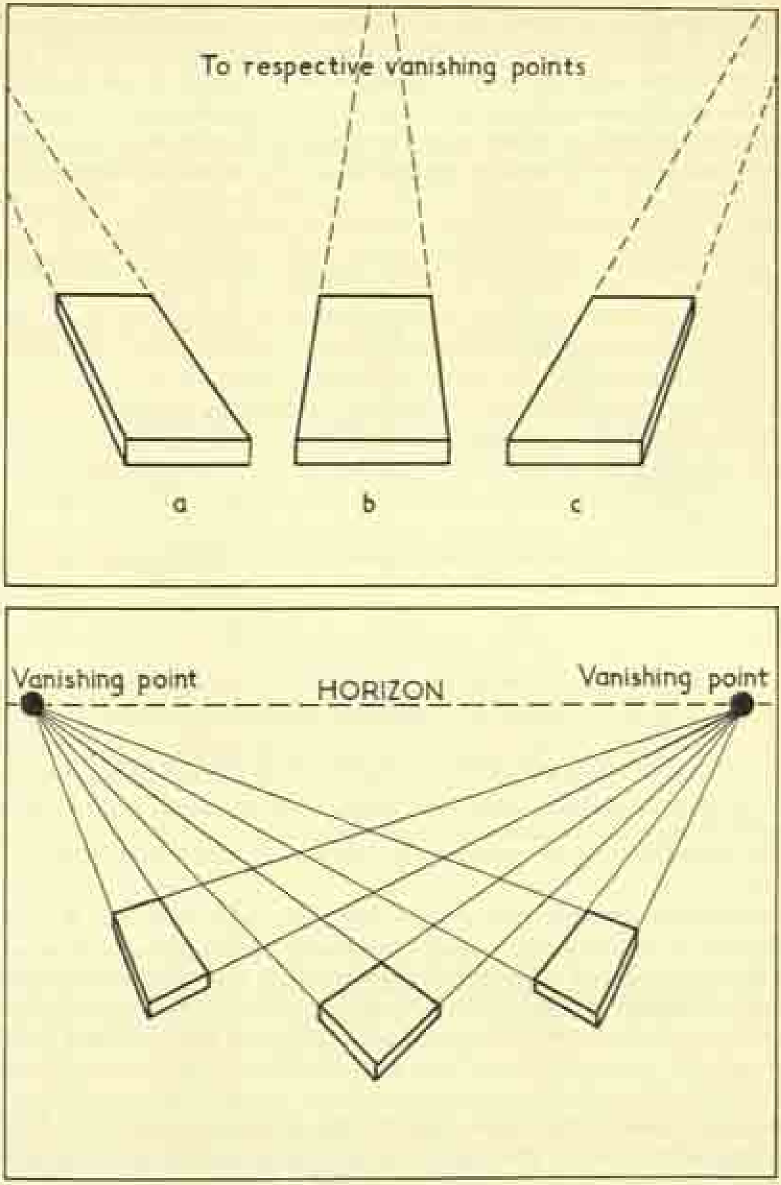
The block-diagrams produced by the methods already described will give a good general effect akin to an oblique view of a relief model. But it will be appreciated that the horizontal and vertical scales are maintained uniformly over the diagram, since the sides of the square and rhombus, and therefore of the grid, are kept identical. The diagram, in other words, is not drawn in perspective. If desired, however, block-diagrams can be constructed in either one-point or two-point perspective, with considerably more labour.

One-Point Perspective

In this case the front of the diagram is a horizontal line, parallel to the back edge, viewed square-on to the observer. The sides of the diagram, and all vertical lines on the plan, converge towards a distant vanishing point on the observer's horizon. The diagram can be placed in several ways to the observer; he may view it face on and see only the front edge, or from one side, either right or left, and see the front edge and a side (Fig. 47). In the latter case, the base angle opposite the observer should be about forty-five degrees.

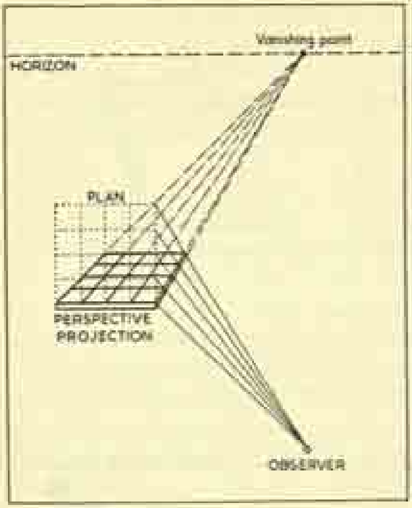
The base-plan, derived from the contour-map and its grid, has to be projected into perspective. Fix the vanishing point some distance away along a table with a pin. Draw the front edge its true size, and,

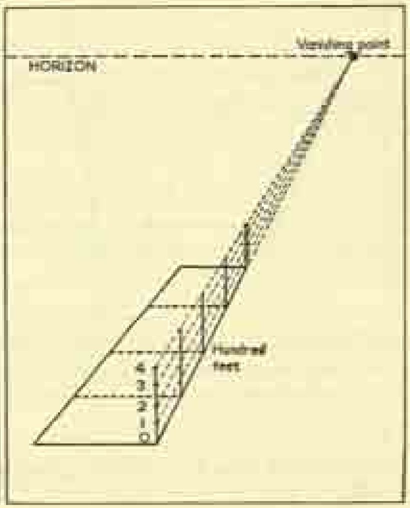
[1] P. T. Dufour, 'Les Perspectives-Reliefs', in *Revue Géographie Annuelle*, vol. 8 (Paris, 1917), describes a device, a form of pantograph, consisting of a long rod, one end of which slides in a groove, the other has a tracer-point, and a pencil, the position of which can be varied, near the centre of the rod. The pencil is placed over the drawing-paper, the tracer over the map, and the contour-outlines are then followed round with the tracer. The pencil reproduces the contours, at any degree of tilt. The paper is moved for each successive contour, as in the ordinary layer method, along the chosen vertical scale. This is a rapid method for simple maps, but is difficult to use with involved contours. The shading and other detail are inserted as for any other method.



FIGS. 47, 48. ONE-POINT AND TWO-POINT PERSPECTIVE BLOCK-DIAGRAMS

using a long ruler, mark the side edges, the vertical grid-lines, and the depth-line to converge at this vanishing point (Fig. 49). To project the back edge of the block, draw lines of view back from the corners of the base-plan to the observer's view-point. Clearly the horizontal scale will decrease from the front to the back of the block; this is naturally involved in the principle of perspective. What is not





FIGS. 49, 50. A ONE-POINT PERSPECTIVE BLOCK-DIAGRAM

Fig. 49 illustrates the method by which the base-plan (shown by pecked lines) is graphically projected into perspective (solid lines).

Fig. 50 indicates how the vertical scale is determined for each perpendicular.

always appreciated is that the vertical scale also decreases. To find this, rule a perpendicular at the front and back corners and also at each intersection of a horizontal grid-line with the edge. Mark off the contour interval on the front perpendicular according to the chosen vertical scale and draw lines from each height to the vanishing point; the correct vertical scale is thus projected upon each perpendicular (Fig. 50). Plot each horizontal section line in the usual way from the base-plan, and transfer the ticks to the projected horizontal. Draw sections according to the particular vertical scale. When the sections have been completed, shading and other detail can be added in the usual way.

No scale should be stated, except in terms of the front edge. More conveniently, under the block can be written: "The distance between *X* and *Y* (two prominent points) is 5 miles", which is quite sufficient

for a block-diagram, while an indication of vertical scale can be given by a few spot-heights.

Two-Point Perspective. In this case, the block-diagrams will present one corner towards an observer and two edges inclined away. The pairs of parallel sides when projected will meet at two vanishing points on the horizon, to the left and right of the observer (Fig. 50). The network of squares on the ground-plan is transferred to the perspective block by ruling lines to these two vanishing points, and then transferring contour intersections with the help of these guide-lines. The changing vertical scales are obtained as for the one-point perspective. This block-diagram allows the geological sections to be shown (Fig. 52).

Perspective Approximations. Both these mechanical methods of attaining perspective are somewhat laborious, and on a small-scale block-diagram perhaps unnecessarily elaborate. When using simple sketch-diagrams of imaginary land-forms, an impression of one-point perspective may be attained by making the back edge slightly shorter than the front and so sloping the sides to it. An impression of two-point perspective can be obtained by making the angle at which the two back edges of the block meet slightly larger than the angle at the front.

Geological Maps

Geological maps are of very great value to the geographer. From the various geological maps available, the physical geographer can obtain much essential data to help his study of land-forms.

The detailed interpretation of geological maps cannot be considered here. The geography student should examine samples of maps published by the British Geological Survey, and consider the detailed schemes of colour, stipple, symbol and lettering used, and the arrangement of the very detailed legends. He should familiarize himself with the method of lettering and numbering of the geological series in order of age. The geographer who wishes to study geological maps in some detail should read the references cited below.[1] In this brief section, it is merely necessary to consider ways in which geological information can be added to relief maps and diagrams.

Reproductions and Tracings

An outline geological map usually accompanies as a matter of course the relief maps illustrating the physical basis of a regional monograph. The main problem is how much detail to show and how to draw and

[1] (*a*) C. Barrington Brown and F. Debenham, *Structure and Surface* (London, 1929); (*b*) R. M. Chalmers, *Geological Maps; the Determination of Structural Detail* (London, 1926); (*c*) A. R. Dwerryhouse, *Geological Maps, Their Interpretation and Use* (London, 1924); (*d*) K. W. Earle, *The Geological Map* (London, 1936); (*e*) G. E. Elles, *The Study of Geological Maps* (Cambridge, 1921).

reproduce it. Fig. 51 shows in outline the main features of Belgium, drawn so as to emphasize specifically the great area of Pliocene sands and gravels which underly the Kempenland. The complexities of the Ardennes, which were not relevant to that study, are masked under solid black, labelled 'Pre-Tertiary Rocks'. Obviously all the details of a large-scale printed map in colours cannot be included, nor would it

FIG. 51. AN OUTLINE GEOLOGICAL MAP

Based on J. Halkin, *Atlas Classique*, Plate 16 (Namur, 1934).

be desirable. The geographer chooses what he needs, and extracts it; examples include maps to show the chalklands of England, the Palaeozoic rocks of the Lakeland Dome, the granite massifs of the South-west Peninsula, the loess of Central Europe, the limestone (karst) of Jugoslavia, and the volcanic areas of the Central Massif of France. These examples can be multiplied indefinitely, and few geography text-books appear without a geological map, of however simplified a nature. The detail must nevertheless be abstracted accurately.

A dissertation map can be hand-coloured, but for a line-block black and white symbols (some of which are depicted on Fig. 17) must be carefully chosen. It should be noted that some symbols for geological

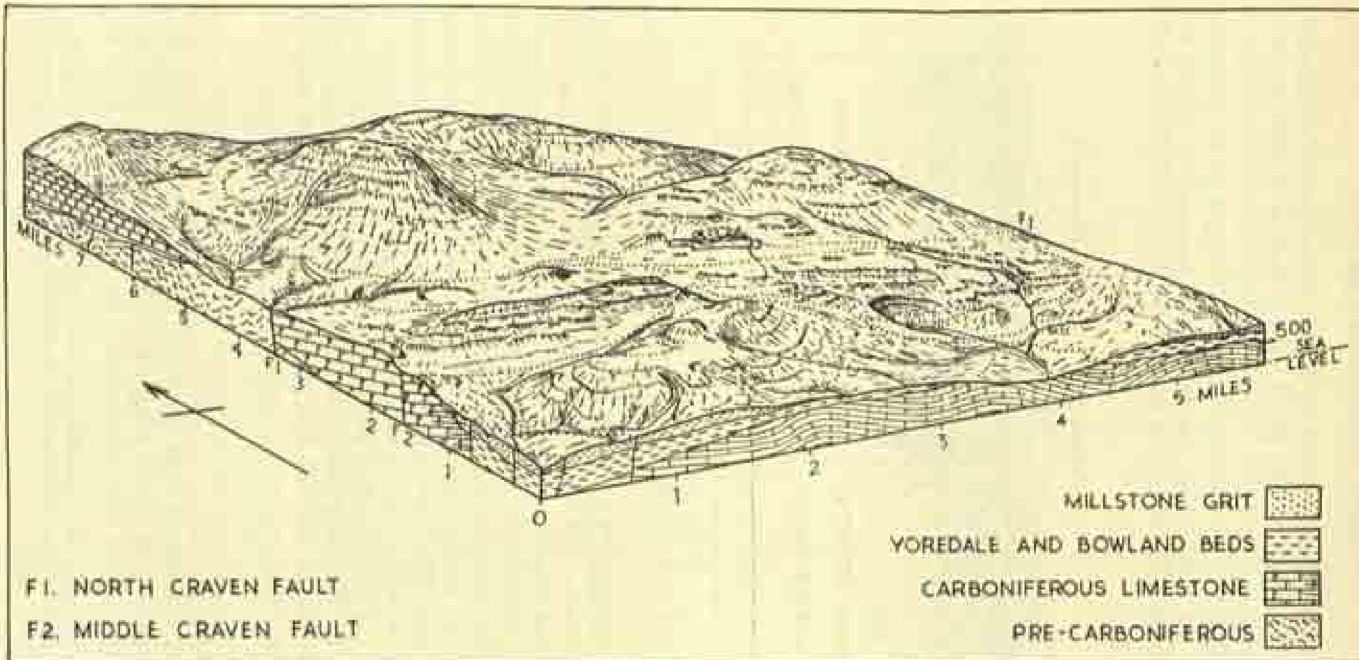


FIG. 52. A TWO-POINT PERSPECTIVE BLOCK-DIAGRAM

The original diagram was compiled by P. Evans, with the assistance of R. G. S. Hudson; original drawing by R. A. Watling. This block-diagram is of the Craven district of the West Riding. In the right foreground lie Malham Cove and Gordale Scar, behind which are Malham Tarn and Fountains Fell. In the background is Pen-y-Ghent. The dotted lines on the surface of the block indicate outcrops.

series have become standardized by usage. A few guides to location, such as rivers and one or two place-names, can be added, but it is difficult to include much detail over close black and white symbols.

One useful device is to superimpose the outline geology on a detailed relief map of the same scale, the former on transparent paper. For example, trace an outline map of part of the Craven Uplands to the

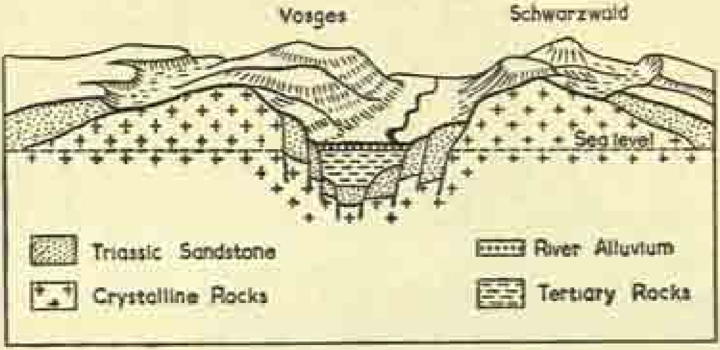


FIG. 53. A BLOCK-DIAGRAM, WITH DIAGRAMMATIC GEOLOGICAL SECTION

Based on A. Cholley, *La France*, p. 110 (Paris, n.d.).

north-west of Malham Tarn on to drawing-paper; extract contours at 250-foot intervals, add streams, mark the pot-holes, and name the main peaks. Then trace an outline map of the solid geology of exactly the same area, maintaining a careful register, from Geological Survey maps; the main outcrops can be lightly tinted. The relationships between relief and geology are most striking when the maps are superimposed; the high fells (the monadnocks of Pen-y-Ghent, Fountains Fell and Ingleborough), the limestone plateau above the mid-Craven fault, the relationship of surface streams and water-sinks to the boundary between the Yoredale Series and the limestone, the position of Malham Tarn, partly on the drift, partly on the exposed Silurian basement of the Pennines, are all emphasized most graphically.

Geological Sections

It is often practicable to add details of the underlying strata to a topographical profile or to the edges of a block diagram, with very great effect (Fig. 52).[1] The information can be obtained from the

[1] A very attractive series of block-diagrams, with the geological detail added to the edges, is given in T. Hagen, 'Wissenschaftliche Luftbild-Interpretation', *Geographica Helvetica*, vol. 5 (Bern, 1950).

geological map itself, or often more conveniently from sections given in the margins of the geological map, from memoirs, or, for detailed large-scale work, from actual observation in the field. The various geological sections include diagrammatic, semi-diagrammatic, and accurate sections.

Diagrammatic Sections. These are usually small-scale, generalized and

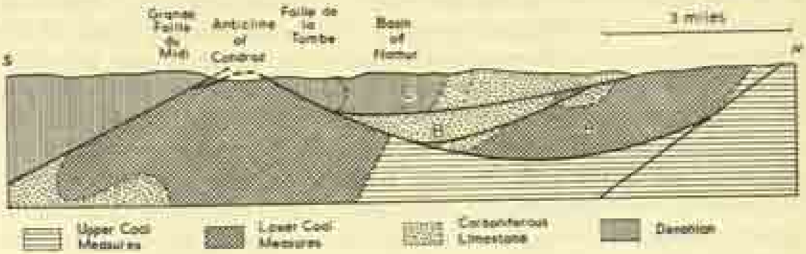


FIG. 54. A GENERALIZED GEOLOGICAL SECTION

Based on A. Briant, 'Etude sur la Structure du Bassin Houiller de Hainaut dans le District du Centre', in *Annales de la Société Géologique de Belge*, vol. 21, p. 125 (Liége, 1894).

This section illustrates, in simplified form, the geological complexity of part of the Sambre-Meuse coalfield of Belgium. The Grande Faille du Midi is a great thrust-fault, along which some of the Devonian rocks of the Ardennes to the south have been driven over the Coal Measures. The letters, **A**, **B**, **C** represent three immense over-thrust wedges, so that shafts have had to be sunk through these overlying Devonian and Lower Carboniferous rocks to reach the younger coal-bearing Upper Coal Measures below.

with a considerable vertical exaggeration, but can be used very effectively to illustrate general concepts of physical geography. The geology may be applied either to a profile or to the edge of a block-diagram. Familiar examples include sections of the Weald, the scarplands of England, the Pennines, the Rhine Rift-Valley (Fig. 53), and the Hercynian folding of central Europe (Fig. 54). Various land-form diagrams (e.g. volcanic cones, sills, laccoliths, unconformities and fault-lines) are made much more clear and graphic when some idea of the solid geology is presented.

Semi-Diagrammatic Sections. A topographical cross-section is first drawn accurately, using as small a vertical exaggeration as possible. Plot on this section the exact points of outcrop from the geological map; at these points the dip of the strata is drawn in by parallel lines. This approximation can only be used for a simple scarpland area, or where the strata have a known dip. The One-inch Geological Survey maps indicate inclined strata by arrows with numbers, showing the direction and amount of dip. If the same stratum outcrops twice, as on opposite

sides of a valley, a line through these two points will give an indication of the dip. The aim of such a section in scarpland country is to illustrate the superposition of the strata, and the dip can only be approximate. In any case, if there is a vertical exaggeration involved, the dip cannot be shown accurately.

To illustrate this method, for example, a profile can be drawn using the One-inch Ordnance Survey series, from Lower Seagry to the Kennet-Og confluence at Marlborough. Then lay a straight edge along the same line of profile transferred to the corresponding sheet of the One-inch Geological Survey series, and mark carefully the outcrops. There is a long succession of these, from the Oxford Clay to the Upper Chalk, with complications of drift (which should be represented by the thinnest possible superficial layer), and it is quite exacting to fit the outcrops to the relief profile. But the result shows very clearly the vales to the west, the various scarp faces, and the long south-eastern dip-slope. To complete the section, ink in the line-work, colour the strata to correspond to a careful legend, add topographical names above the section, and finish off the usual details of horizontal and vertical scales, vertical exaggeration, orientation and title.

Accurate Sections. These are used mainly by mining- or water-engineers, and are constructed usually from direct information obtained in the field. They must be drawn without any vertical exaggeration, or the dip will be falsified. The actual drawing of accurate sections involves the determination of *strike* (the line of intersection of a bedding surface with a horizontal plane), of *true dip*, which is at right-angles to the strike, and of *apparent dip*, which is a direction of slope at some angle between the strike and the true dip. Once the direction and amount of the dip has been established, the topographical section is drawn, the points of outcrop are plotted, and the strata are drawn in at the correct angle. In the case of anticlines or synclines there will be two opposite directions of true dip with the axis of the fold between. Faults introduce further complications.

The drawing of exact sections is somewhat outside the province of the geographer, and it is impossible to go into this here. The student is referred to the works cited on p. 105.

CHAPTER III

CLIMATIC MAPS AND DIAGRAMS

DATA

THE chief *primitive elements* of climate include radiation from sun and sky, temperature, wind direction and velocity, humidity, evaporation, cloud and sunshine, precipitation, snow-cover and atmospheric pressure. Each element is capable of further subdivision, for example, precipitation comprises hail, snow and rain; all may be measured by direct observation. *Combined elements* are those which are usually calculated by means of combining two or more elements, although some, such as humidity, may be directly observed. Examples include equivalent temperature (temperature and water-vapour pressure), drying power (saturation pressure, water-vapour pressure and wind velocity), cooling power (temperature, wind velocity and humidity), and continentality (solar radiation and temperature). Finally, there are other elements which may be referred to as *derived elements*.[1] They include the variabilities, ranges, frequencies, probabilities and intensities of the various elements.

Published climatological data may include primitive, combined or derived elements; classification of data is therefore complex and variable. An infinite variety of information may be available for some parts of the world, and comparatively little for others.[2] From the point of view of the geographer, primarily interested in climate rather than in weather, mean values for the various elements are of greater significance than actual measurements. Mean values are generally understood to reflect 'average weather', i.e. climate, but abnormal weather conditions cannot be overlooked. As W. G. Kendrew states: "The abnormal weather conditions are very important, for the possibility of abnormally long or severe frost, or of a prolonged drought in a region which is usually well-watered, is the final consideration which may override for practical affairs of life the value of the mean conditions."[3] Tables of mean values therefore must be supplemented by reference to actual weather conditions, information about which is conveniently provided in synoptic charts. Not only do these charts bring together the elements which the climatologist is apt to separate

[1] V. Conrad, *Methods in Climatology* (Harvard, 1944).

[2] See *World Weather Records*, Smithsonian Miscellaneous Collections, vols. 79, 90, 105 (Washington, various dates), and International Meteorological Organization *Réseau Mondiale, 1911–32* (published by British Meteorological Office, 1917–39).

[3] W. G. Kendrew, *The Climate of the Continents*, p. 6 (Oxford, 1927).

one from another, but they also bring reality to his somewhat abstract conception of climate.

Temperature

Daily Means. Where thermograph records of temperature are available, *true daily means* can be calculated. The mean is determined of twenty-four hourly observations; an example is given in the table below.

Hours	*Observations in Degrees Centigrade*												*True Daily Mean*
	1	2	3	4	5	6	7	8	9	10	11	12	
A.M.	16·1	15·8	15·4	15·1	14·8	15·0	16·1	17·4	18·5	19·4	20·3	21·1	18·6
P.M.	21·9	22·6	22·7	22·5	21·9	21·0	19·8	18·8	18·1	17·5	17·0	16·6	

The term *daily mean* is used where only a limited number of observations is available. In the International Meteorological Code this is assumed to be the mean of daily observations taken at 07, 1400, and 2100 hours, and the use of the following formula is advocated:

$$\textit{Daily Mean}\ (^\circ C) = \frac{\textit{Readings at } 07 + 1400 + 2100 + 2100 \textit{ hours}}{4}$$

Thus using the observations given in the table above,

$$\textit{Daily Mean}\ (^\circ C) = \frac{16\cdot1 + 22\cdot6 + 18\cdot1 + 18\cdot1}{4} = 18\cdot7$$

Where only the maximum and minimum temperatures for the day are available, the *daily average temperature* can be found by averaging the two, for example:

$$\textit{Daily Average}\ (^\circ C) = \frac{\textit{Maximum Temperature} + \textit{Minimum Temperature}}{2}$$

$$= \frac{22\cdot7 + 14\cdot8}{2} = 18\cdot8$$

Monthly Means. The *true monthly mean* is a weighted and corrected average of the temperature of each observation hour throughout the month, but the *monthly mean* is obtained simply by averaging the daily means. For climatological purposes the monthly means of specific years are less important than averages for each month over a long period, usually thirty-five years or more. Monthly means relating to long periods constitute the chief data of the climatologist in his analysis of

temperature. But in addition to monthly means he must have details of mean monthly maxima, mean monthly minima, the absolute monthly maximum and the absolute monthly minimum temperatures.[1]

Annual Means. True annual mean temperature is a weighted and corrected average of true daily means for the year, but the *annual mean* is obtained by averaging the monthly mean temperatures. A slight inaccuracy results because each month is not of the same length. Annual mean temperatures have a general comparative value, but they are used chiefly in the determination of long-term temperature trends.

Significant Means, Extremes and Ranges. Mean and extreme diurnal ranges in temperature can be obtained from a comparison of maxima and minima figures. In addition to these basic data, some tables contain information about significant temperatures and their average or median dates of occurrence. For example, the highest and lowest temperatures ever recorded and their dates of occurrence, the average dates of the first and last killing frosts, the average dates of the rising or the falling of mean daily temperatures through 32°F and through 42°F (the temperature above which most plants begin to grow). Such information is particularly useful to the agricultural geographer.

Rainfall

Precipitation may be measured by a standard rain-gauge which is read daily, or, less usually, by a self-recording instrument. From these measurements a number of records are compiled which are of interest to the geographer.

Monthly Means. For general purposes the monthly means of rainfall are simply arithmetic means of the total rainfall for each month over a period of years.[2] Sometimes, however, it is useful to reduce all months to an equal length in order to avoid false deductions, as, for example, if a comparison has to be made between February and August. This reduction may be effected in two ways: (*a*) The amounts for the 31-day months are reduced by 3·2 per cent and the amount for February is increased by 6·2 per cent. Hence each month is made equivalent to 30 days. (*b*) All months are altered to become months which are one-twelfth of a year (i.e. 30·438 days). Therefore, the amount for February has to be multiplied by 1·077 (1·049 in leap years), for 30-day months by 1·015, and for 31-day months by 0·982.

Monthly means of rainfall are useful for illustrating the mean average distribution of rainfall throughout the year at any one station. Means, however, give no indication of the nature of the rainfall, whether heavy

[1] See *Averages of Temperature for the British Isles, for periods ending 1935* (M.O. 407, 1936).

[2] See Meteorological Office, *Average Monthly Rainfall of the British Isles, 1881–1915*, by M. de C. S. Salter (Reprint, *British Rainfall*, London, 1920).

or light, whether reliable from one year to another, whether effective in connection with plant growth. A great deal of additional information is therefore necessary to a proper understanding of this element of climate.

Monthly and Yearly Totals. In many countries of the world details of the rainfall are published year by year. *British Rainfall*, for example, published by the Meteorological Office of the Air Ministry, incorporates information about total rainfall for each year for a number of stations in the British Isles. Yearly summaries of the total monthly rainfalls are also published.

The Number of Rain-days and Wet Days. *British Rainfall* also incorporates data concerning the number of *rain-days* in each year, i.e. days having more than 0·01 inch of rainfall, and the number of *wet days*, i.e. days having over 0·04 inch of rainfall. It should be noted that in some other countries a 'rain day' is considered to be a day with over 0·1 inch.

Rain Spells, Wet Spells, Droughts and Dry Spells. In *British Rainfall* there are tables giving information about *rain-spells*, i.e. durations of at least 15 consecutive rain-days, *wet spells*, i.e. durations of at least 15 consecutive wet days, *absolute droughts*, i.e. durations of 15 or more consecutive days none of which has 0·01 inch of rain or more, *partial droughts*, i.e. durations of 29 or more consecutive days, the mean rainfall of which does not exceed 0·01 inch, and *dry spells*, i.e. durations of 15 consecutive days or more, none of which has 0·04 inch of rainfall or over.

Intensity of Rainfall. The rate at which rain falls is obviously related to problems of run-off, soil percolation, evaporation, soil erosion and flood control. Information about intensity of rainfall is therefore just as vital to an understanding of rainfall regimes as are mean values of total rainfall. Unfortunately, data about rainfall intensities are not very satisfactory, because there are few stations equipped with a reliable pluviograph or with sufficient personnel to make eye observations during rain-spells.

Most climatic tables do, however, give some information about the hourly duration of rain and about the amount of rainfall for a limited number of stations. Where such information is available, mean hourly or daily intensity of rainfall can be calculated using the formula:

$$I = \frac{A}{N}$$

where A = total rainfall over a given period and
N = total number of hours of rain, or number of rain-days.

Using this formula, the intensity of rain at Boston, Mass., is, for

example, 0·36 compared with 4·17 at Cherrapunji. Hourly intensities give better comparative results than do daily intensities.

Duration of Rainfall is compiled from pluviographic records. Tables of duration give the annual and monthly values in hours of rainfall for individual stations.

Deviations from Mean Rainfall are usually tabulated in the form of excess or deficiency of the total for any one month or year over the means; these data are of use in the analysis of rainfall probability (see p. 148).

Effectiveness of Rainfall is usually taken as the actual total rainfall minus the total possible evaporation. There are numerous ways of measuring possible evaporation none of which is entirely satisfactory. The Piche evaporimeter is commonly used, in which water in a tube is allowed to evaporate from a piece of porous paper, and the loss in a given time is measured on a scale graduated on the tube. Some evaporation statistics are calculated from measurements taken of the level of water in large open tanks. Various experiments have been made to measure evapo-transpiration, i.e. loss from evaporation plus moisture lost by plant transpiration. Potential evapo-transpiration rates are used in the calculation of moisture requirements of the soil, and in the determination of relative regional aridity (see p. 131).

Snowfall and Hail are for record purposes usually measured by melting the solid precipitation and including it in the rainfall total as if it were rain. In addition, records are kept of the number of days in the year on which snow and on which hail fall, the number of days per year with snow lying, the duration of continuous snow-cover, mean and greatest snow-depth, and intensity of snow or hail-fall.[1] In the British Isles snowfall is so comparatively rare that records can be kept of individual falls of particular intensity.

Wind

Wind force is measured at certain fixed hours by direct observation of such an instrument as an air-meter or Robinson Cup Anemometer; at the same time its direction is recorded from a well-exposed weather-vane. The Dines Tube Anemometer produces an anemograph yielding continuous records of both direction and force. Wind direction and wind force are related and wind data can be analysed more efficiently by a consideration of both aspects at the same time rather than independently. Also duration of wind force and direction varies considerably during the day and the most valuable statistics indicate the time of observation. Because of all the measurements involved, wind tables take up quite a lot of space and are, perhaps, the most difficult of all weather data to express cartographically. Until 1949, when most

[1] See tables in, Meteorological Office, *The Baltic Sea* (London, 1947).

countries of the world agreed to adopt the recommendations of the International Meteorological Organization, a variety of codes was in use whereby wind direction and force were measured. In British returns, for example, direction was usually expressed in terms of a number of cardinal points of the compass, and force in terms of the Beaufort Scale. Revised codes of force have now been drawn up, and returns of wind directions are made as true bearings in tens of degrees.[1] Most geographers, however, will find themselves working with average data assembled previous to 1949, of which the more important are summarized below.

Monthly Means of Wind Force and Direction. The number of occasions out of a hundred on which particular winds may be expected at different times of day, in different months and from different directions, are tabulated according to four, five, or more scales of wind force. Unfortunately, such information is not available for many places over a long period of years, but where it is available, it provides the bulk of the evidence about local winds.

Gust Levels. It is necessary to realize that statistics concerning wind velocity are usually expressed as a mean value for the period of observation, and 'gustiness' cannot be estimated from such figures. The *Gustiness Factor* (G) published for various stations provides some means of calculating local gustiness if mean wind velocity is known. For example, if G is 0·5 for a mean wind velocity of 40 miles an hour, then gusts as high as 50 or as low as 30 miles an hour may be expected; if G is 1·0, then gusts of 60 miles an hour may occur.

Mean Diurnal Variations of Wind Direction. Changes in wind direction between day and night are particularly important in certain coastal regions, where land- and sea-breezes are experienced.

Resultant Wind Direction and Force. The average wind force from a given direction in miles per hour multiplied by the number of hours it blows from that direction in any given period is known as *mean of wind*, expressed in miles per hour. If these data are available for any station it is possible to calculate from them the average resultant wind velocity, the average resultant wind direction, and the average 'steadiness' of wind at that particular station.[2] Occasionally these data are available in tabular form, and they are of use in plotting streamlines by means of arrows (see pp. 165-7).

Sunshine and Cloud

Duration of sunshine is measured by the Campbell-Stokes recorder, which produces a continuous record in the form of a line burnt upon

[1] See, Meteorological Office, *International Meteorological Code* (London, 1948).

[2] For details of computation, see V. Conrad and L. W. Pollak, *Methods in Climatology* 2nd edition (Cambridge, Mass., 1950).

a strip of cardboard. Tables of mean sunshine data are compiled upon the basis of absolute duration in hours per day, or month, or upon the basis of percentage of possible sunshine per day or month.[1]

Degree of Cloudiness. Cloudiness is related to sunshine, but discrepancies in records occur partly because sunshine recording instruments are not perfect, partly because the degree of cloudiness is observed usually only three times a day, while its measurements is extremely difficult because of the great variety of cloud. It is usually expressed in tenths, for example, one-tenth of the sky clouded, two-tenths, and so on. Tables are compiled of mean cloudiness upon daily, monthly and yearly bases.

Humidity

Data concerning humidity are normally obtained from readings of dry- and wet-bulb thermometers at fixed hours, but thermohygrographs do provide continuous readings.[2] There is a variety of modes of expression of the data, but *relative humidity*, which represents

Relative Humidity: Monthly Means and Diurnal Ranges

Aberdeen	*Jan.* %	*Feb.* %	*Mar.* %	*Apr.* %	*May* %	*June* %
Highest mean hourly value	81·8	81·6	83·0	84·4	86·1	86·4
Daily mean	80·7	79·6	78·7	78·0	78·5	78·1
Lowest mean hourly value	78·0	75·4	72·1	70·5	71·8	71·2
Diurnal range	3·8	6·2	10·9	13·9	14·3	15·2

Aberdeen	*July* %	*Aug.* %	*Sept.* %	*Oct.* %	*Nov.* %	*Dec.* %	*Year* %
Highest mean hourly value	86·4	87·1	86·3	86·0	83·8	83·4	84·6
Daily mean	78·5	79·5	80·3	82·4	82·1	82·3	79·9
Lowest mean hourly value	71·3	70·9	71·9	75·2	78·5	80·0	74·0
Diurnal range	5·1	16·2	14·4	10·8	5·3	3·4	10·6

Source: E. G. Bilham, *The Climate of the British Isles* (London, 1938).

the percentage degree of saturation of the air, is of major interest to the geographer because of its importance for human comfort and for plant growth.

Diurnal Variation of Relative Humidity is considerable, and mean daily figures therefore have not any great significance. Mean monthly statistics are compiled, but it is more usual to give monthly means for a specific time during the day, or to give additional information about mean diurnal ranges, as the above table illustrates.

[1] See *Averages of Bright Sunshine for the British Isles* (M.O. 408, 1936).

[2] See *Averages of Humidity for the British Isles* (M.O. 421, 1938, reprinted 1949).

Visibility

Visibility observations are usually taken several times a day according to specified scales. Mean data are usually compiled upon the basis of the old scale, but it should be noted that a new scale has recently been proposed by the International Meteorological Organization.[1] These observations are compiled on a frequency percentage basis, usually in the form of mean monthly visibility frequencies at 07, 13 and 18 hours respectively.[2] Occasionally tables are compiled which give the frequency of different degrees of visibility, expressed as a percentage of the total number of winds from each of several directions.

Synoptic Charts and Weather Summaries

Reference has already been made to the value of synoptic charts and of weather summaries in providing an occasional salutary corrective to the abstract concept of climate associated with the element-by-element analysis of mean data. Weather charts are valuable in another way, in that they provide a time record of total weather conditions; this can be analysed in much the same way as mean data to provide a more comprehensive concept of average weather in different places at different times.[3]

Analysis of information about total weather conditions recorded in weather charts since about 1900 for Great Britain, parts of Europe and North America, undertaken in the first place by weather forecasters, has proved to be of great significance to the climatologist. The relationship between pressure systems, direction of air-flow, and types of weather can, it is true, be laboriously established by analyses of mean data, but the problem is better dealt with by reference to synoptic charts. The object of such analyses is to establish the 'ingredients' of climate in the form of characteristic types of weather, and to find the seasonal and annual incidence of such types of weather.

The Calendar of Singularities. Singularities in the weather which are sufficiently regular in their occurrence from year to year can be tabulated in the form of a calendar. Examples of such singularities in British weather are as follows:

(*a*) *Late Autumn Rains—last week in October and first fortnight in November;*

[1] For the old scale see *Instructions for the Preparation of Weather Maps, with Tables of the Specifications and Symbols* (London, 1946). For the new scale see, Meteorological Office, *International Meteorological Code* (London, 1950).

[2] Examples of such tables are given in Meteorological Office, *The Bay of Biscay and the West Coast of Spain and Portugal* (London, 1944).

[3] See the following publications of the Meteorological Office: the *Daily Weather Report*; the *Monthly Supplement* to the Daily Weather Report; the *Daily Aerological Record* (contains information about upper air conditions); and *Monthly Weather Report* (contains summaries from about 420 stations in the British Isles).

(b) *Early Spring Anticyclones—third week in March;*
(c) *Northerly Weather—first fortnight in May.*[1]

No completely reliable calendar of singularities has yet been compiled, but work already done does indicate the episodal changes in our weather in contradistinction to broad seasonal changes.

Characteristic Types of Weather based on Pressure Systems. The frequency with which certain types of weather is associated with specific isobaric patterns suggests a profitable approach to the analysis of weather charts. E. G. Bilham (*op. cit.*) has indicated how E. Gold's classification of pressure systems for forecasting[2] may be simplified for climatological purposes into seven categories of weather, the average seasonal frequency of which can be determined by an examination of weather charts.

Spells of Weather. Analyses of daily weather charts have been made from time to time with the object of defining 'natural seasons' in terms of the frequency of long spells of weather. A 'natural season' in this sense is characterized by a high frequency of persistent weather, and 'average natural seasons' are demarcated by short spells of weather. H. H. Lamb, on the basis of such an analysis, suggests a seasonal division of the British Isles into five instead of four (see p. 137).

Data in daily and monthly weather charts may ultimately be utilized for the purpose of defining climatic regions. For example, J. R. Borchert has shown that such data might be applied to the definition of the North American Grassland.[3] In his case, the data extracted from the weather charts were used to determine the mean frequency of air-flow from different directions over the interior of the North American continent (see p. 166).

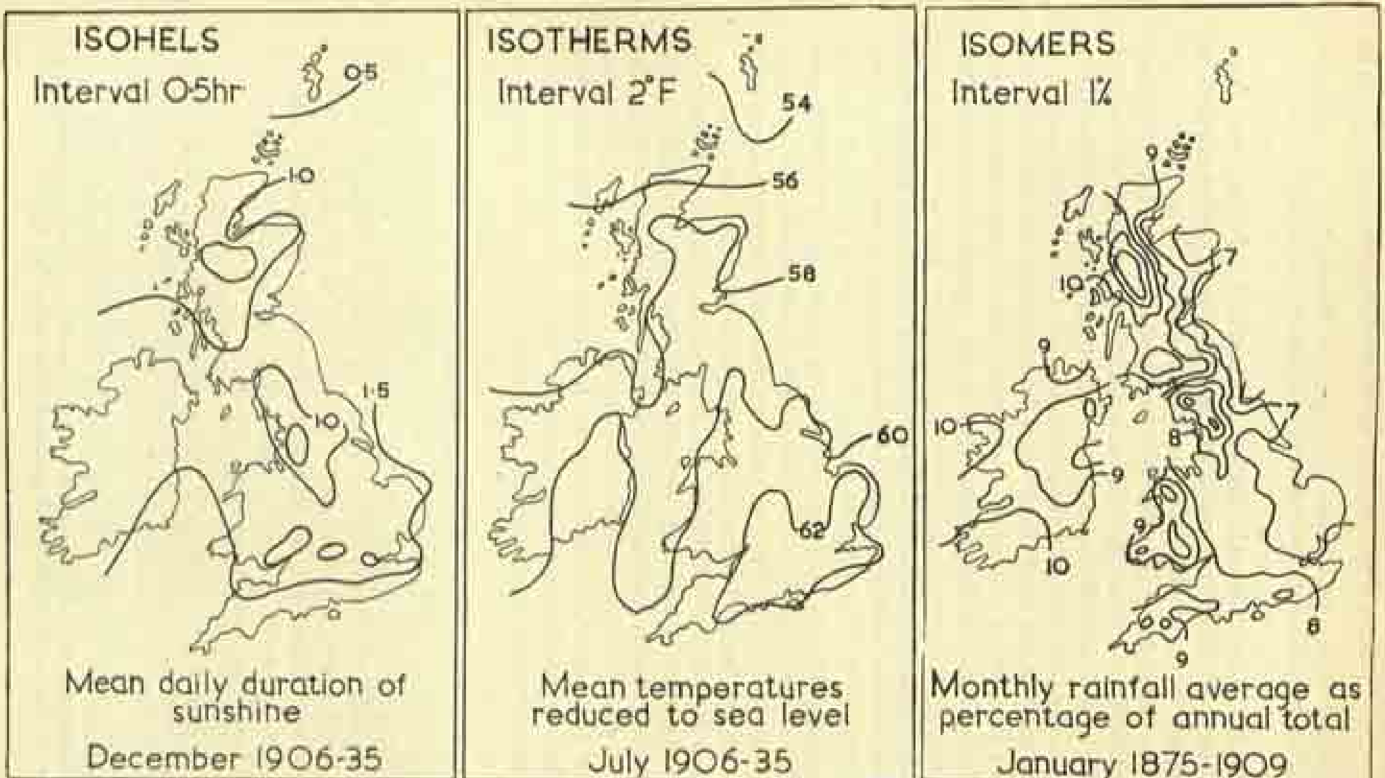
Isopleth Maps

Representation of climatic data by isopleths is the most important single cartographic method used by climatologists. It can be applied almost equally effectively to any aspect of climate. Isopleths may be interpolated (see p. 30) for places having the same mean values of temperature (isotherms), of rainfall (isohyets), of pressure (isobars), of sunshine (isohels), of frost (isocrymes), of clouds (isonephs), of relative humidity, and so on (Figs. 55–7).

[1] H. H. Lamb, 'Types and Spells of Weather in the British Isles', *Quarterly Journal of the Royal Meteorological Society*, vol. 76, no. 330 (London, 1950).

[2] E. Gold, 'Aids to Forecasting', *Geophysical Memoir*, no. 16 (H.M.S.O., London 1920). See also two papers by R. B. M. Levick, 'Fifty Years of English Weather', and 'Fifty Years of British Weather', *Weather*, vols. 4, 5 (London, 1949 and 1950).

[3] J. R. Borchert, 'The Climate of the North American Grassland', *Annals of the Association of American Geographers*, vol. 40, no. 1 (Lancaster, Pa., 1950).



FIGS. 55–7. CLIMATIC ISOPLETHS

Based on (1) E. G. Bilham, *The Climate of the British Isles* (London, 1938); and (2) H. R. Mill and C. Salter, 'Isomeric Rainfall Maps of the British Isles', *Quarterly Journal of the Royal Meteorological Society*, vol. 41 (London, 1915).

Isobars

In the case of isobars, interpolation of observed daily values requires some appreciation of the structure of pressure systems, otherwise the delineation of fronts is likely to be obscured by over-simplification. The most practical manner of overcoming this particular difficulty is to attempt to draw the isobars from the tabular observations given

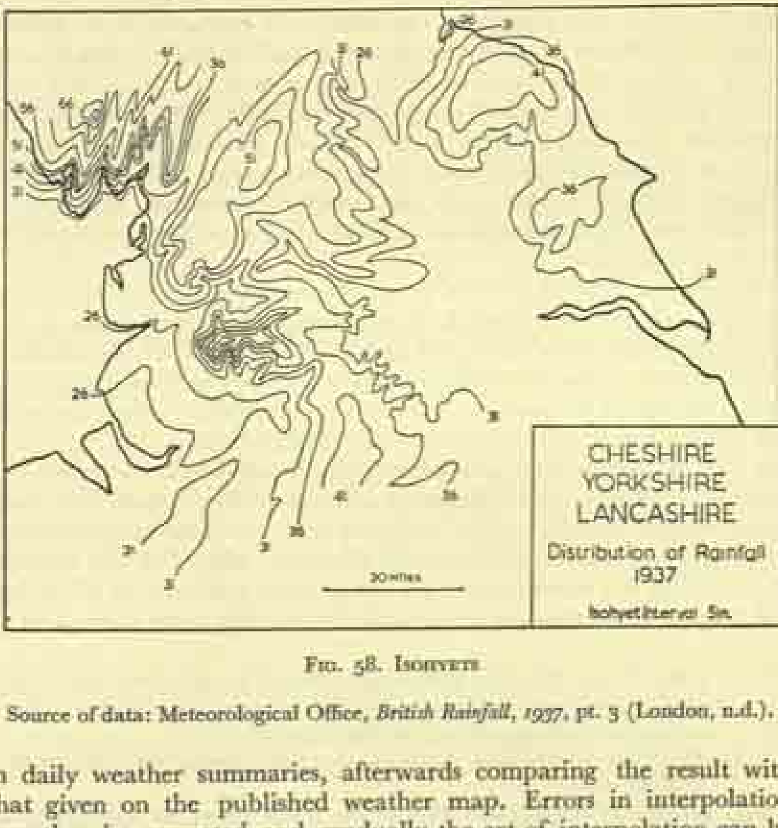


FIG. 58. ISOHYETS

Source of data: Meteorological Office, *British Rainfall, 1937*, pt. 3 (London, n.d.).

in daily weather summaries, afterwards comparing the result with that given on the published weather map. Errors in interpolation may then be corrected and gradually the art of interpolation can be mastered.[1]

Isobars may also be drawn to depict mean pressure systems, but these are less valuable than those representing typical isobaric patterns associated with certain weather conditions. Attention may be drawn here to two maps showing the distribution of typical weather conditions over the surface of the earth at the time of the solstices.[2]

[1] For a full discussion of the problems of drawing isobars, see S. Petterssen, *Weather Analysis and Forecasting* (New York, 1940).

[2] M. A. Garbell, *Tropical and Equatorial Meteorology* (London, 1947).

The conditions are shown by isobaric patterns, with their fronts also delineated.

Isohyets

The interpolation of isohyets presents special problems. An example with reference to a specific region will serve to exemplify some of these problems. Fig. 58 shows the distribution of rainfall in 1937 in Lancashire, Yorkshire and Cheshire. The data were extracted from *British Rainfall, 1937*; there are many hundreds of stations given in the tables, but only those which received daily means were selected, and less reliable stations were ignored unless gaps had to be filled in the scatter of stations. The total rainfall of each station selected was plotted in pencil on a base-map on a scale of ten miles to one inch. V. Conrad advocates the use of base-maps on a smaller scale than this, but if they are used it becomes difficult to make allowances for modifications due to relief factors.[1]

Selecting the isopleth interval presents something of a problem. The interval to be selected depends on the range of rainfall totals to be plotted, the character of the region under consideration, that is, whether coastal or interior, flat or mountainous, the scale of the base-map, and, finally, the aim of the map, i.e. whether it is intended to show general distribution or significant features of the distribution.

In Fig. 58 the general distribution of rainfall has been shown by means of a progressive arithmetical interval of five inches. The isohyets were carefully drawn with reference not only to the plotted values (see p. 90), but also to the localized effects of relief. For this reason, the draft map was superimposed on a good relief map and the following tendencies, which apply generally in the British Isles, were allowed for:[2]

(*a*) *Total rainfall increases with height (average increase from one-and-a-half to two inches per hundred feet at the coast and rather less than one-half to three-quarters of an inch inland)*;

(*b*) *Maximum precipitation normally occurs just beyond the crest on the leeward side;*

(*c*) *Increase in precipitation with height begins before the actual rise in elevation and the rate of increase is more than proportional to the increase of the gradients;*

(*d*) *Valleys surrounded by mountains have high rainfalls;*

(*e*) *In the case of a valley running in the same direction as the prevailing rain-bearing winds, a tongue of lower rainfall will extend up the valley;*

[1] V. Conrad, *op. cit.*

[2] See J. Glasspoole, 'The Rainfall of Norfolk', *British Rainfall, 1928* (London, 1929); and 'The Rainfall of the Forth Valley and the Construction of a Rainfall Map; *British Rainfall, 1915* (London, 1916).

(*f*) *In the case of a valley which lies transverse to the rain-bearing winds, rainfall will be heavier on the valley side facing the wind;*

(*g*) *In Britain the prevailing rain-bearing winds should be taken to be west-south-westerly.*

Shading and Tinting. Finally, the distribution of the isohyets may be clarified if intervening areas are shaded. Layer tinting is effective, but

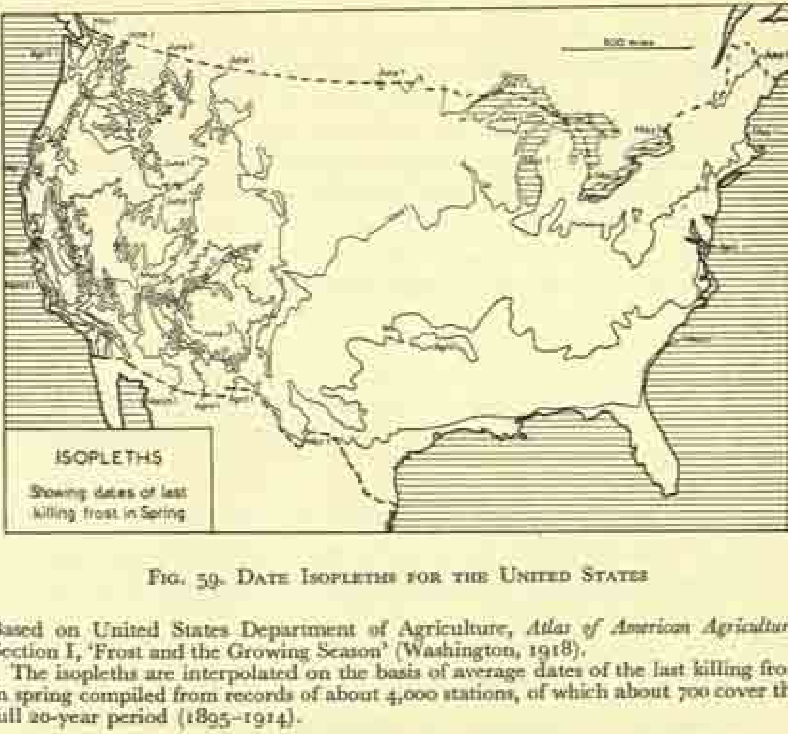


FIG. 59. DATE ISOPLETHS FOR THE UNITED STATES

Based on United States Department of Agriculture, *Atlas of American Agriculture*, Section I, 'Frost and the Growing Season' (Washington, 1918).

The isopleths are interpolated on the basis of average dates of the last killing frost in spring compiled from records of about 4,000 stations, of which about 700 cover the full 20-year period (1895–1914).

if a variety of colour tints is employed the range and sequence of colours need careful consideration. An effective scheme is one which represents low rainfall in red and progressively heavier rainfall in shades of brown, yellow, green, blue and white.[1] On the maps in *British Rainfall, 1943–45*, four shades of red and four shades of blue are used, but unfortunately dark red is used for areas of lightest rainfall and light red for areas of heavier rainfall; the maps would have been more effective had the representation been reversed.

[1] See the rainfall maps in *Atlas de France*, Comité National de Géographie (Paris, 1933).

Isopleths of Duration

Isopleths can be used effectively to show the distribution of places experiencing a similar duration of particular mean weather conditions. For example, the mean duration of a growing season can be illustrated in this way, as revealed by the number of days when the average daily temperature exceeds 42°F. The growing season of any particular crop can be mapped in the same way, for example, cotton, where the critical temperature is 63°F. Similarly, the mean duration of the season of killing frosts, the mean duration of snow cover,[1] the mean duration of special rainfall intensities, and the mean daily duration of sunshine,[2] can also be illustrated by isopleths.

Date Isopleths

Duration and seasonal changes of mean weather conditions may also be depicted by isopleths which join places experiencing similar changes in temperature, rainfall, etc., on the same date (Fig. 59). Date isopleths of this kind are effectively used in showing climatic distributions and seasonal changes over the great land masses.[3] Date isopleths are commonly used to show the progress of a monsoon in terms of mean dates of arrival of the first rains. They may also be used to delimit climatic zones.[4] Again they can be used on the basis of median and percentile values to indicate probability of certain weather conditions on particular dates, for example, a fifty per cent probability of frost, etc.[5]

Frequency Isopleths

These isopleths depict places which have the same mean frequency of climatic phenomena, expressed as the number of days or the number of occasions per year, or other period, on which they occur. Some of the more obvious examples include the mean number of wet days, rain-days and droughts, and of days with fog[6] and snow.[7] Less obvious

[1] See maps in *The Climatological Atlas of Japan* (Tokyo, 1949).

[2] See a series of maps in E. G. Bilham, *The Climate of the British Isles* (London, 1938).

[3] Good examples may be found in the United States Department of Agriculture, *Atlas of American Agriculture* (Washington, 1936). *The Great Soviet World Atlas* (Moscow, 1938) includes many climatic maps of this type; one series, for example, shows the mean dates of change of daily average temperature through −10°C, −5°C and 0°C in periods both of rising and falling temperatures.

[4] M. Jefferson, 'Standard Seasons', *Annals of the Association of American Geographers*, vol. 28 (Lancaster, Pa., 1938), makes use of them in this connection. See also H. M. Kendall, 'Notes on Climatic Boundaries in the Eastern United States', *Geographical Review*, vol. 25 (New York, 1935).

[5] See in this connection, E. E. Lackey, 'A Variability Series of Isocrymal (Equal Frost) Maps of Alaska', *Geographical Review*, vol. 26 (New York, 1936).

[6] See map in E. G. Bilham, *op. cit.*, p. 275.

[7] See examples in Admiralty Geographical Handbooks, *France*, vol. 1, and *Germany*, vol. 1.

examples include the mean number of days with ice-bound rivers, the mean number of months per year with air-streams from specific directions,[1] and the mean frequency of characteristic types of weather.

Isanomals

An example of the use of 'method of differences' in climatic studies is the calculation of anomalous temperatures and their plotting by means of isanomals (isopleths of anomalies). In order to demonstrate seasonal differences, mean monthly temperatures are generally used. The *norm* for any latitude is taken to be the average of the mean monthly temperature experienced in that latitude. This is found in practice by averaging the mean monthly temperature, reduced to sea-level, for a number of well dispersed stations in the latitude. Tables of standard distribution of temperatures with latitude are helpful.[2] Standard temperatures may also be found by the formula,[3]

$$t = -17{\cdot}8 + 44{\cdot}9 \cos^2 (\theta - 6{\cdot}5)^\circ C,$$

where θ is the latitude.

The temperature anomaly for any particular station is the amount by which its mean monthly temperature departs from that of the norm. The anomalies are plotted and isanomals (lines joining places with the same anomaly) are interpolated. Regions of high positive anomaly are known as *pleions* (*thermopleions* in the case of temperature) and regions of high negative anomaly as *meions* or *antipleions* (*thermomeions* in the case of temperature). Positive anomalies are sometimes tinted red for effect, and negative tinted blue.[4]

An application of this method is the plotting of isanomals to show anomalies of temperature conditions in a mountainous country, particularly between northward- and southward-facing slopes. In this case temperatures are not reduced to sea-level, but are related to the mean temperatures of a number of selected stations dispersed over the countryside at different elevations.[5]

[1] P. R. Crowe makes use of frequency isopleths of 50, 70 and 90 per cent constancy to show the limits of the trade-winds in 'The Trade Wind Circulation of the World', *Institute of British Geographers. Transactions and Papers, 1949*. Publication no. 15 (London, 1951).

[2] Such a table is to be found in V. Conrad (*op. cit.*).

[3] J. D. Forbes, 'Inquiries about Terrestrial Temperature', *Transactions of the Royal Society of Edinburgh*, vol. 22 (1859).

[4] See B. C. Wallis, 'Geographical Aspects of Climatological Investigation', *Scottish Geographical Magazine*, vol. 30 (Edinburgh, 1914), in which the idea of anomalies is illustrated by twelve monthly world maps.

[5] See a map in V. Conrad and L. W. Pollak, *op. cit.*, p. 278, entitled 'Isanomalies of vegetative period in Switzerland'.

Equipluves

Equipluves are lines joining places with the same pluviometric coefficients. The pluviometric coefficient for any month is arrived at by expressing the mean monthly rainfall total for a given station as a ratio of the hypothetical amount equivalent to each month's rainfall were the total rainfall for that station to be equally distributed throughout the year. For example, Ponta Delgada (37° 44′ N., 25° 40′ W.) has the following mean monthly rainfalls in inches:

J	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*	*Total*
3·0	2·9	2·5	2·1	2·1	1·3	0·8	1·4	2·5	3·3	3·4	3·2	28·5

Using the above values:

$$\textit{The pluviometric coefficient for January} = \frac{3{\cdot}0}{28{\cdot}5\left(\frac{31}{365}\right)} = 1{\cdot}4$$

The coefficients may be expressed as percentages in order to eliminate decimals.[1]

Equivariables

Isopleths may be used with effect in plotting the distribution of places with similar deviations from their average weather conditions.[2] For example, the mean annual rainfall figures for any given station do not reflect the reliability of rainfall at that station, for the figures may represent the means of a number of actual totals widely dispersed on either side of the mean. The exact degree of variability is difficult to compute, and various statistical formulae have been derived to represent it in the form of a *coefficient of variability*. One such formula used in its calculation is as follows:

$$CV = \frac{\sigma}{M}\ (100)$$

where CV=coefficient of variability, σ=standard deviation and M=the mean value.

Standard deviation is obtained by the formula,

$$\sigma x = \sqrt{\frac{\Sigma(x^2_n)}{N}}$$

where σ=standard deviation, x_n=deviations from the mean, and N=the total number of observations upon which the mean is calculated.

[1] B. C. Wallis, 'The Rainfall of Java', *Scottish Geographical Magazine*, vol. 33 (Edinburgh, 1917).

[2] For an example, see A. V. Williamson and K. G. T. Clark, 'The Variability of the Annual Rainfall of India', *Quarterly Journal of the Royal Meteorological Society* vol. 57 (London, 1931).

A simple example is considered below.

Year	*Rainfall (inches)*	x	x^2
1920 . .	2·0	−2	4
1921 . .	4·0	0	0
1922 . .	8·0	+4	16
1923 . .	2·0	−2	4
1924 . .	4·0	0	0
Total . .	20·0	—	24·0

Arithmetic mean=4·0 *inches*

$$\therefore \sigma = \sqrt{\frac{24}{5}} = \sqrt{4{\cdot}8} = \pm 2{\cdot}2 \textit{ inches}$$

$$\therefore CV = \left(\frac{2{\cdot}2}{4{\cdot}0}\right)100 = 55 \textit{ per cent}$$

The coefficient of variability is usually expressed as a percentage as above. Generally speaking, it is found that places with low average rainfall have a high coefficient of variability, although not necessarily so.

Median values of rainfall (see p. 158) can also be used to measure variability. C. E. Hounam, in an analysis of Australian rainfall, uses the formula:[1]

$$CV = \left(\frac{\textit{Inter-quartile Range}}{\textit{Median}}\right)100$$

Isopleths interpolated to join places with equal coefficients of variability might be termed *equivariables*.

In some cases it is of interest to show how the rainfall totals of one particular year differ from the means of previous years. Coefficients need not be worked out in this case, but the observed one-year totals can be expressed simply as percentages of mean totals. Isopleths are then interpolated.[2]

Equivariables can be drawn equally well to show variability of the mean values of temperatures, variability of the mean date of killing frost, variability of the mean length of growing season and so on.[3] Such maps obviously have great value in their application to agricultural problems, and they are also of use in the delimitation of climatic regions.

[1] Commonwealth of Australia, Meteorological Bureau, *Climate of the West Australian Wheat Belt with Special Reference to Rainfall over Marginal Areas* (Melbourne, 1945).

[2] A number of maps of this type is to be found in the *British Rainfall* series, published by the Meteorological Office.

[3] Examples of such maps may be found in the *Atlas of American Agriculture*, *op. cit.*

Equicorrelatives

Isopleths indicating correlations of climatic data may be termed equicorrelatives. It is often difficult to correlate two or more sets of climatic data by inspection. For example, sets of annual totals of rainfall over a period of years for two stations might exhibit certain relationships, but such related characteristics can only be measured with a fair degree of accuracy by statistical methods. If the degree of relationship between two sets of rainfall statistics can be expressed in the form of a single index, then the distribution of places having similar relationships can be easily plotted on a map. Statisticians refer to such indices as *correlation coefficients*. They establish the degree to which two sets of statistics are related, the inference being in the case of rainfall statistics that some common cause is at work if the correlation is relatively close. Thus correlations can be used as a basis for climatic differentiation.

The Coefficient of Correlation. A short method of computing correlation coefficients for two or more sets of annual rainfall data is based on the formula:

$$r=\frac{\dfrac{\Sigma(xy)}{N}-\bar{x}\bar{y}}{\sigma x \sigma y}$$

where r=the coefficient of correlation, x=value of annual precipitation for one station, y=value of precipitation for the second station, $\bar{x}$=mean annual value for the first station, $\bar{y}$=mean annual value for the second station, σx and σy=standard deviations (*see* *p.* 126), *and N=number of years of observations.*

Isopleths may be interpolated to join places of equal correlation coefficient of rainfall after such coefficients have been plotted on the map.[1] Coefficients with a value approaching +1 may be considered as having a close direct relationship; in the case of those approaching −1, an inverse relationship is to be assumed, whilst values near zero indicate chance relationships only.

Isomers

The term 'isomeric' is often used to describe a method of studying regional variations in the relative proportions of rainfall falling in each month of the year.[2] The mean monthly rainfalls for each station in the region under consideration are 'weighted' and expressed as percentages of the respective mean annual rainfalls. Twelve maps can

[1] For a good example of the application of this method see E. E. Foster, 'A Climatic Discontinuity in the Areal Correlation of Annual Precipitation in the Middle West', *Bulletin of the American Meteorological Society*, vol. 25 (Milton, Mass., 1944).

[2] H. R. Mill and C. Salter, 'Isomeric Rainfall Maps of the British Isles', *Quarterly Journal of the Royal Meteorological Society*, vol. 41 (London, 1915).

then be drawn to show the distribution of comparative proportions of rainfall for each month by means of isopleths joining places with similar percentages (see Fig. 57). The method is clearly capable of wide applications in the case of other climatic data.

Isopleths of Temperature Range

The isopleth method can be used most effectively to show the distribution of the mean range of annual temperature,[1] the mean range of diurnal temperature,[2] and the range of extreme temperatures, diurnal and annual, together with the highest and lowest extremes recorded.

Isopleths of Accumulated Temperature

Not a great deal of work has been done by climatologists on accumulated temperatures, but they may have significance in schemes for classification of climates, in the study of relationships between plant activity and temperature conditions, and in the analysis of climatic cycles. They are usually calculated from the mean daily temperatures experienced at any one station over a period of time. The values above or below significant thresholds, such as 32°F, 42°F or 65°F, are added together for the period under consideration and expressed as a single accumulated value usually in terms of day-degrees. Thus, if 42°F is taken as the threshold and the mean daily temperature for January 1st is 49°F, it would count as +7 day-degrees towards the final total. To cut down the laborious calculations necessitated by the use of daily means, estimates based on monthly means may be used. Thus if the January monthly mean is 45°F, it would count as,

$$31 \times 3 = 93 \textit{ day-degrees}$$

towards the final total.[3]

Distribution of accumulated temperatures may be shown by isopleths interpolated in the usual manner (Fig. 60). They may be drawn to indicate accumulations for specific months or seasons, or for the whole year.

[1] See maps in W. G. Kendrew, *The Climates of the Continents*, p. 70 (Oxford, 1927), and in E. G. Bilham, *op. cit.*, p. 151.

[2] See an interesting map in E. G. Bilham, *op. cit.*, p. 167.

[3] For a more refined method of calculation of accumulated temperatures, see Meteorological Office, Form 3300, *Tables for the Evaluation of Daily Values of Accumulated Temperature above and below 42° Fahrenheit from Daily Values of Maximum and Minimum Temperature*. Graphical methods of calculating temperature accumulation by means of an *ogive* or cumulative temperature curve, are discussed by C. E. P. Brooks, *Climate in Everyday Life*, p. 238 (London, 1950). Data required for exact measurement comprise hourly readings of temperature, but Brooks' method only requires certain selected means and extremes.

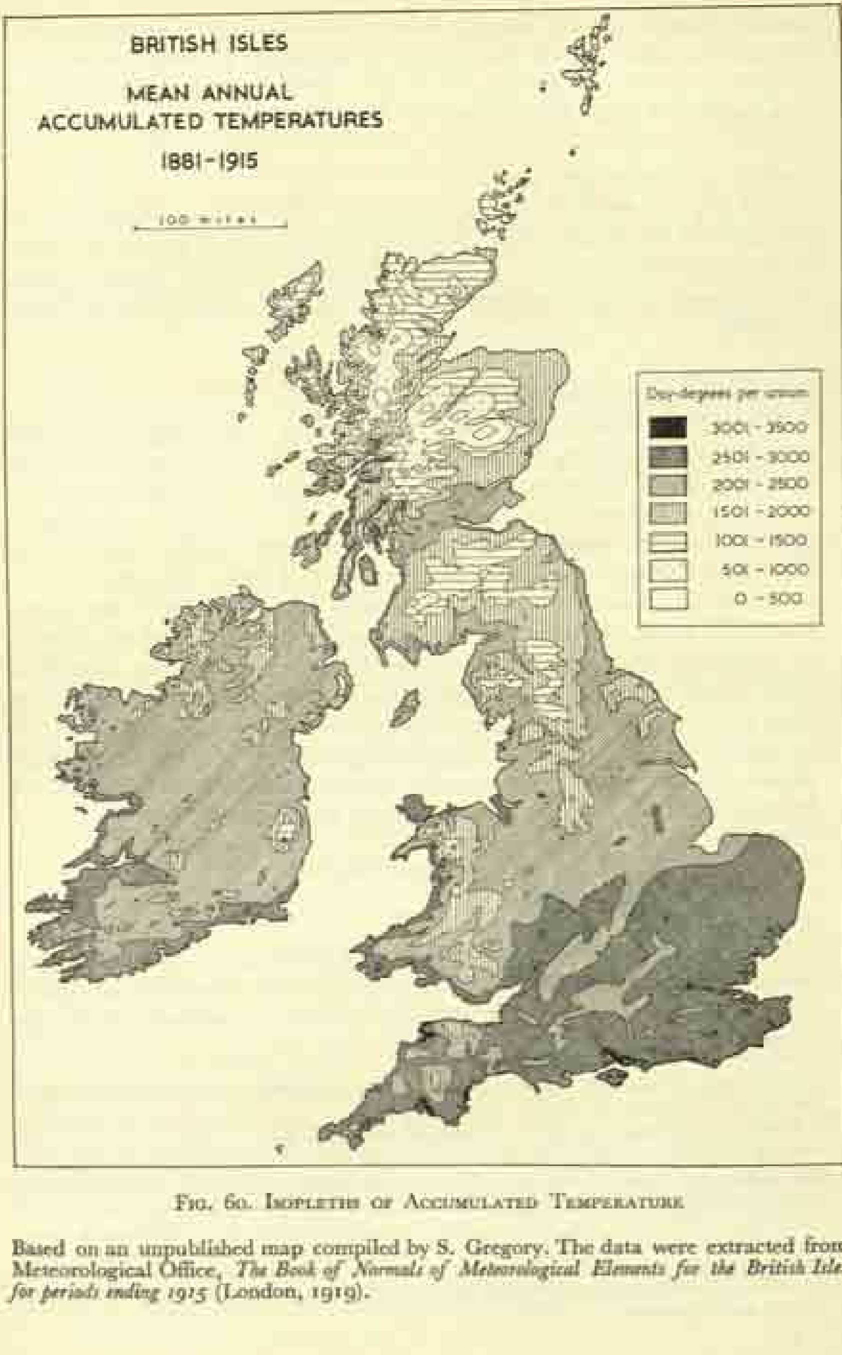


FIG. 60. ISOPLETHS OF ACCUMULATED TEMPERATURE

Based on an unpublished map compiled by S. Gregory. The data were extracted from Meteorological Office, *The Book of Normals of Meteorological Elements for the British Isles for periods ending 1915* (London, 1919).

Isopleths of Aridity and Moisture

Various ingenious formulae have been devised both by climatologists and botanists to give an indication of climatic aridity which might be of use both in the rational delimitation of climatic regions and in agricultural planning. Such indices have particular reference to the study of relationships between natural vegetation and climate. The simplest index is perhaps that suggested by R. Lang:[1]

$$\textit{Rain Factor} = \frac{\textit{annual precipitation in millimetres}}{\textit{mean annual temperature in °C}}$$

Slightly more complex is de Martonne's index,[2] which has been used with great effect for the plotting of a series of pleasing maps in the French National Atlas.[3] De Martonne's index is as follows:

$$I = \frac{P}{T+10}$$

where I is the index of aridity, T is the mean annual temperature in °C, and P is the mean annual rainfall in millimetres.

Monthly indices are given by the formula:

$$i = \frac{p \times 12}{t+10}$$

where t=mean monthly temperature and p=mean monthly rainfall.

The two formulae are made commensurate so that annual and monthly maps may be compared.

C. W. Thornthwaite has made convincing use of empirical relationships between rainfall, temperature and evaporation in the classification of the climates of North America, and his methods are being applied to the climates of other parts of the world. Thornthwaite's formula for finding monthly precipitation-evaporation ratio, *P/E*, is:

$$i = 11{\cdot}5\left(\frac{p}{t-10}\right)^{10/9}$$

The summation of the twelve monthly values, multiplied by 10 to

[1] R. Lang, *Verwitterung und Bodenbildung als Einführung in die Bodenkunde* (Stuttgart, 1920).

[2] E. de Martonne, 'Aréisme et Indice d'Aridité', *Comptes Rendus de l'Académie de Science de Paris*, vol. 182 (Paris, 1926).

[3] For another application see J. Gottman, 'Une Carte de l'Aridité en Palestine', *Annales de Géographie*, vol. 45 (Paris, 1936).

avoid decimals, gives the value for the year.[1] The index values range from 0 to about 150. They are divided into five categories—wet, humid, subhumid, semi-arid, and arid. Thornthwaite has also produced corresponding temperature categories by devising a thermal efficiency factor, calculated from the formula,

$$i = \frac{t - 32}{4}$$

where i = thermal efficiency factor and t = mean monthly temperature.

Thornthwaite has further pointed out in one of his later papers that evaporation and transpiration from plants (evapo-transpiration) cannot be satisfactorily calculated from mean temperature figures, but that the potential rate of evapo-transpiration may be calculated with the aid of specially devised formulae. The evapo-transpiration formula is involved, and has to be solved with the aid of a nomograph. Moreover, there are certain adjustments to make to the result because of variations in the duration of daylight and in the lengths of months.[2] Once potential evapo-transpiration has been ascertained, it is comparatively easy to calculate the water surplus and deficiency for any station during the course of the year (see p. 144).

The various indices discussed above lend themselves readily to cartographical expression by means of isopleths, and the completed maps effectively demonstrate fundamental climatic differences from one region to another.

Columnar Diagrams

Columnar diagrams, because of their clarity and because of their ease of construction, are particularly effective in the depiction of certain aspects of climatic data. They can be used to show the rhythm of diurnal and seasonal changes, the distribution of regional variations by superimposition upon locational base-maps (Fig. 61), and the range and variability of various climatic elements.

Simple Columnar Diagrams

In its simplest form each vertical column represents a number of units of rainfall, sunshine, etc., for a particular period of time, for example, by monthly periods to show seasonal variation, by 24-hour

[1] C. W. Thornthwaite, 'Climates of North America', *Geographical Review*, vol. 21 (New York, 1931).

[2] Formulae, nomograph and tables are to be found in C. W. Thornthwaite, 'An Approach towards a Rational Classification of Climate', *Geographical Review*, vol. 48 (New York, 1948).

periods to show daily variation. In the latter case, columns representing hours of darkness are sometimes shaded black, and those representing hours of daylight are left white.[1] For seasonal comparisons, data relating to calendar months may be used, but where some detailed

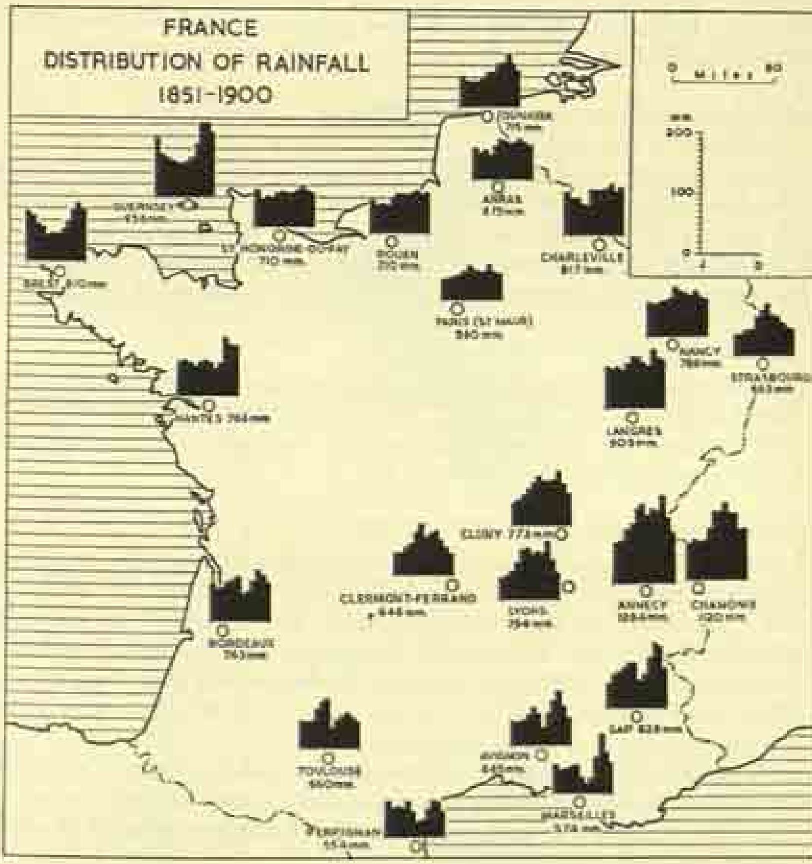


FIG. 61. LOCATED COLUMNAR DIAGRAMS OF RAINFALL

Source of data: E. Alt, 'Klimakunde von Mittel-und-Südeuropa', pt. 1, vol. 3, pp. 150–6, W. Köppen and R. Geiger, *Handbuch der Klimatologie* (Berlin, 1938).

analysis of seasonal distribution of data is being attempted, it becomes necessary to make allowances for differences in the number of days in each month (see p. 113).

Simple columnar diagrams may be constructed to show total amounts

[1] See examples in Sir Napier Shaw, *Drama of the Weather* (Cambridge, 2nd edition, 1939).

of rainfall (Fig. 61), of evaporation, of run-off, and of sunshine, or they may be adapted to show frequencies, for example, of the number of days with fog, snowfall or hail, the number of wet days, rain-days, and days with good visibility.[1] Accumulated temperatures are also often depicted in this way.[2] Significant heights, such as the height of freezing level, and the depth of frost penetration below ground, are also suitably depicted by means of the simple columnar diagram.

Percentage Columnar Diagrams

Where it is required to compare inter-regional mean monthly variations of specific weather elements, percentages are more effective than absolute totals. The vertical columns are made to represent, for example in the case of rainfall, the percentage of the yearly precipitation for each month, or, in the case of sunshine, the actual sunshine experienced in each month, as a percentage of the possible sunshine for that month.

Superimposed Columnar Diagrams

Columnar diagrams of different stations may be superimposed for direct comparison (Figs. 62–3). Superimpositions of various elements can be made on the same diagram, for example, of mean rainfall, evaporation, percolation and run-off.[3]

Compound Columnar Diagrams

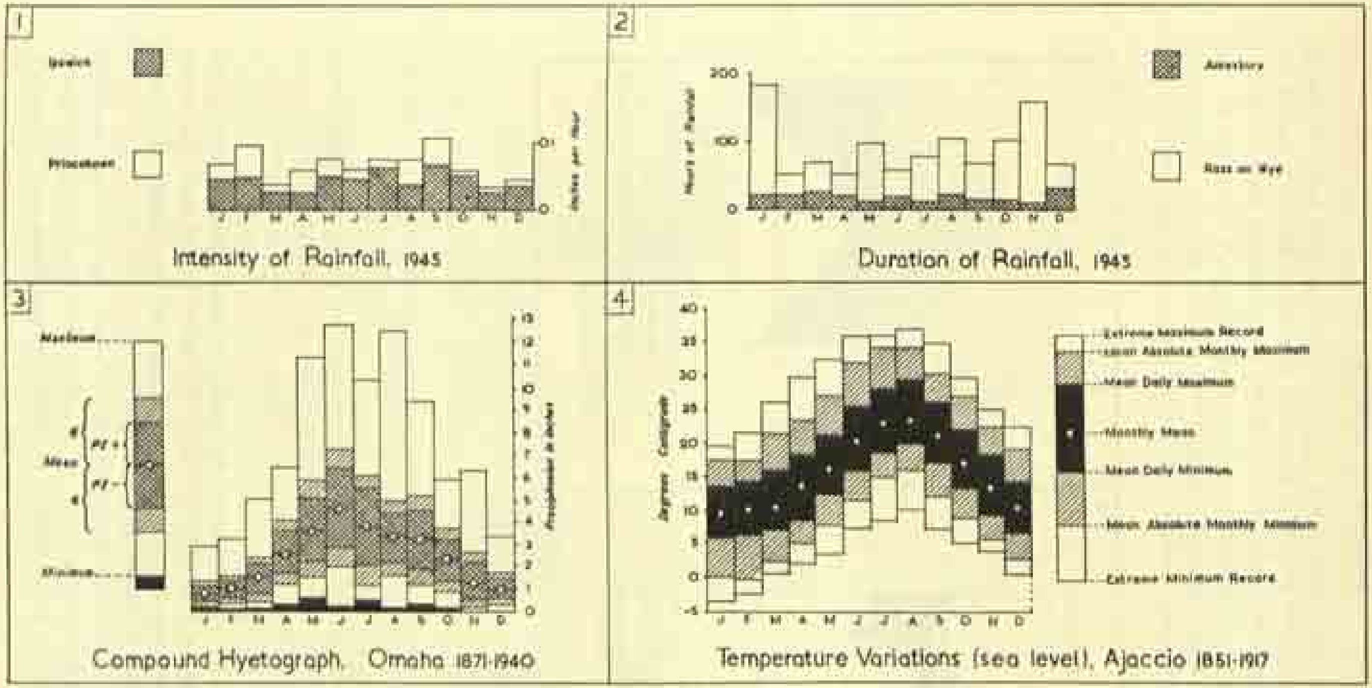
Columnar diagrams may be used with effect to show the 'make-up' of certain averages. Thus a column showing precipitation for December for a station in northerly latitudes may be subdivided to show the relative importance of snowfall compared with rainfall. Similarly, columns may be subdivided to show moderate and poor visibility, to show wind direction, or to show the amount of rain falling at night compared with that in the daytime.

Deviations from mean conditions may also be effectively depicted by columnar devices. For example, columns may be constructed to show the maximum, the mean and the minimum rainfall in each month, and still further elaboration may be introduced by indicating the standard deviation and the probable deviation of rainfall from the accepted mean (Fig. 64, and see p. 126). Such diagrams are known as *hyetographs*. Some information about dispersion of rainfall may be

[1] Numerous examples of this type of columnar diagram are used to illustrate the regional monographs on weather published by the Meteorological Office, such as *Weather on the West Coast of Tropical Africa* (M.O., 492, 1949).

[2] See a good example in G. Manley, 'The Range of Variation in the British Climate', *Geographical Journal*, vol. 117 (London, 1951).

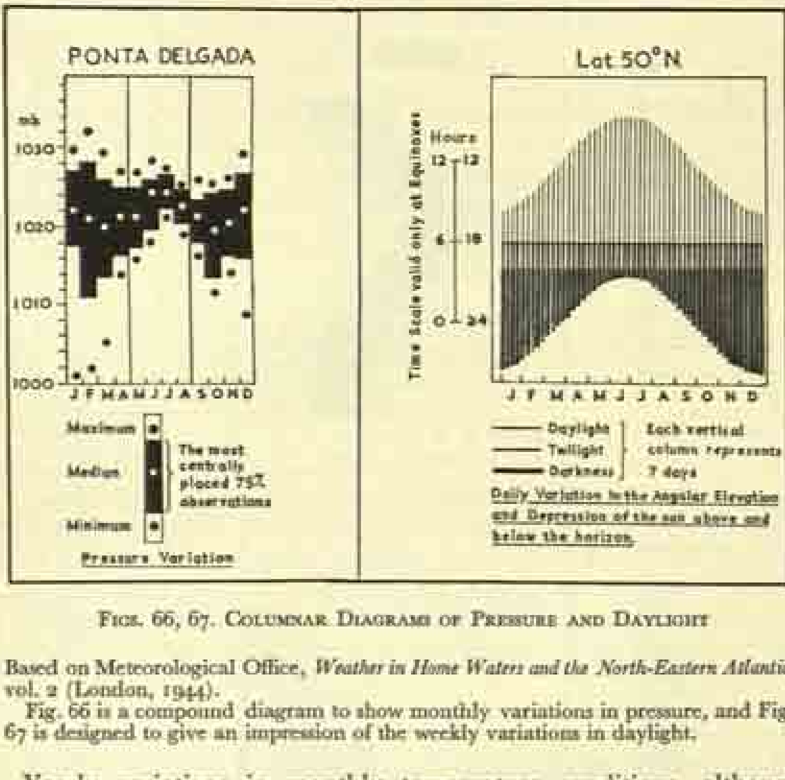
[3] Some good examples are in F. Shreve, 'Rainfall, Run off and Soil Moisture under Desert Conditions', *Annals of the Association of American Geographers*, vol. 24 (Lancaster, Pa., 1934).



FIGS. 62–5. COLUMNAR DIAGRAMS OF RAINFALL AND TEMPERATURE

1 and **2** consist of columns superimposed for purposes of comparison. Source of data: Meteorological Office, *British Rainfall, 1943–1945* (London, 1950). **3** is based on E. E. Foster, *Rainfall and Run-off* (New York, 1949). It exemplifies a compound diagram to illustrate the maximum and minimum rainfall over a period of years for each month, together with the standard deviation (σ) and the probable error (*PE*). The source of data for **4** is *World Weather Records*, Smithsonian Miscellaneous Collections, vol. 79. It exemplifies a compound diagram to illustrate monthly variations in temperature over a period of years.

included by the indication of the position of median and quartile points (see p. 158). Fig. 66 shows a pressure variation diagram based on frequency of pressure conditions in which the maximum and minimum records are indicated, together with the median. A fair idea of the more normal range of variation is given by the area in solid black which covers the most centrally-placed 75 per cent of the observations.



FIGS. 66, 67. COLUMNAR DIAGRAMS OF PRESSURE AND DAYLIGHT

Based on Meteorological Office, *Weather in Home Waters and the North-Eastern Atlantic*, vol. 2 (London, 1944).

Fig. 66 is a compound diagram to show monthly variations in pressure, and Fig. 67 is designed to give an impression of the weekly variations in daylight.

Yearly variations in monthly temperature conditions, although usually depicted by line-graphs (see p. 138), may occasionally be more effectively illustrated by columnar devices (Fig. 65). Columns depicting extreme temperatures recorded in each month, the absolute monthly maxima and minima, the daily maxima and minima, and the monthly means give a fairly comprehensive idea of both the range of temperature from month to month and of the range of diurnal temperature during each month.

Analyses of characteristic types of weather made from synoptic records are sometimes capable of graphic presentation in columnar form. It is possible, for example, to show average frequency of specific

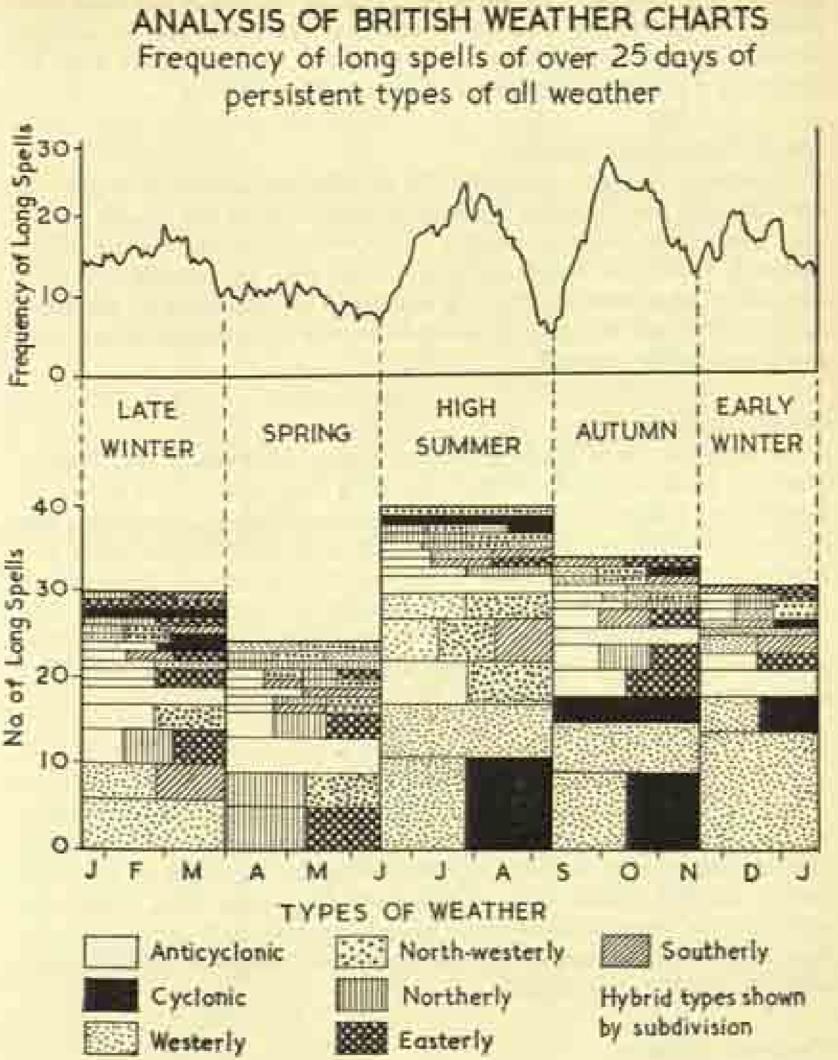


FIG. 68. TYPES AND SPELLS OF WEATHER ANALYSED BY MEANS OF A FREQUENCY CURVE AND DIVIDED RECTANGLES

Source of data: H. H. Lamb, 'Types and Spells of Weather in the British Isles', *Quarterly Journal of the Royal Meteorological Society*, vol. 76, no. 330 (London, 1950).

air-mass types in each month of the year by means of columns subdivided in accordance with the number of types selected for study.[1] Again, the make-up of seasons in terms of weather types may be shown by a compound columnar diagram (Fig. 68).

Special Columnar Diagrams

Columnar diagrams are useful in elucidating aspects of insolation and climate, for example, latitudinal variations in the length of the day, and in the angle of the sun's rays relative to the surface of the earth. A variety of diagrams of this type may be worked out with the aid of almanacs. In Fig. 67 variations in the angle of the sun's rays at different latitudes have been shown by columns made proportionate to the angles.

Weather Integrals

An unusual use is made of the columnar diagram by Sir Napier Shaw in an illustration entitled 'Nature's Integrals'.[2] It is a type of cumulative polygraph in which the accumulated temperatures, the amounts of sunshine, amounts of rainfall, amounts of evaporation and amounts of daylight for each week in the year are all plotted, but arranged cumulatively so that each amount is represented by columns and successive columns are placed in steps (Fig. 69). The whole diagram summarizes admirably the average expectancy of the chief elements throughout the year.

LINE-GRAPHS

A wide variety of graphs is used in the illustration of different aspects of climate, and the methods selected for discussion below have been chosen largely with the idea of stimulating the ingenuity of the individual student rather than of covering the whole field. Once the principles of graphic illustration have been mastered, special graphs may be evolved for special purposes, and tried methods modified and adapted to serve new ends.

Continuous Tracings

Continuous records made by self-recording instruments constitute one type of graph. Such graphs may be of use to the climatologist in illustrating characteristic sequences of weather conditions, for example,

[1] Thus E. M. Frisby and F. H. W. Green illuminated a quantitative analysis of air-mass types in south-east England with the aid of the columnar technique in 'Further Notes on Comparative Regional Climatology', *Institute of British Geographers, Transactions and Papers, 1949*, Publication no. 15 (London, 1951).

[2] *Drama of the Weather*, 2nd edition (Cambridge, 1939).

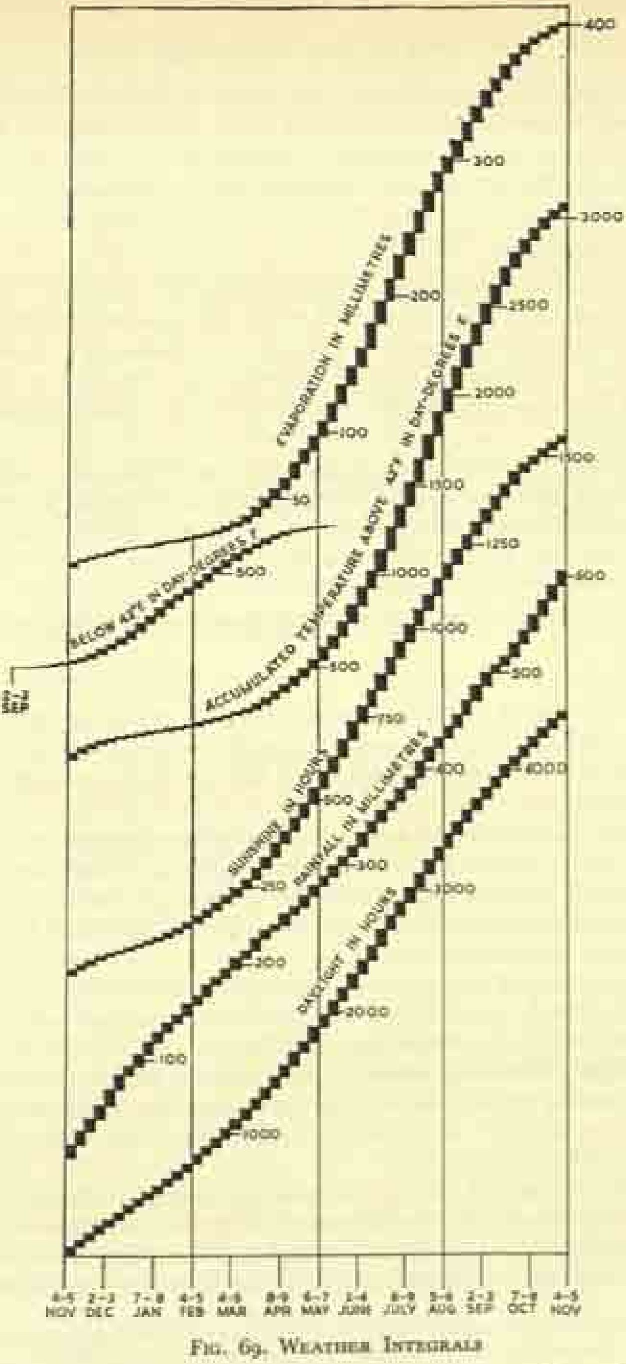


FIG. 69. WEATHER INTEGRALS

Based on Sir Napier Shaw, *Drama of the Weather*, p. 290 (Cambridge, 2nd edition, reprinted 1939).

those associated with the passage of a depression. Relationships between pressure, temperature, rainfall and wind are self-evident from such graphical records. But continuous tracings are by their very nature of more use in the illustration of weather than of climate.

Simple Line-Graphs

In the conventional type of Cartesian graph, amounts of temperature, humidity, evaporation, and so on are plotted as ordinates, and months of the year, hours of the day, etc., as abscissae, to show seasonal or diurnal variations. Regional variations in climate can be demonstrated by comparing graphs which portray the conditions for selected type-stations.

Sometimes comparisons of seasonal variability are facilitated if amounts of temperature and of other data are reduced to percentages (see below). Direct comparisons of varying conditions may also be shown on one graph—for example, by plotting amounts of mean January temperature as ordinates, and certain type stations, arranged either in order of magnitude or by geographical location, as abscissae.

Polygraphs

A series of multiple line-graphs, drawn on the same chart to show relationships between two sets of climatic statistics at one station, or between sets of similar statistics for two or more stations, comprise a polygraph.

Climatic type summaries constitute the most familiar type of polygraph. These consist essentially of two line-graphs, to indicate temperature and rainfall regimes respectively. In practice, however, to enable a ready distinction to be made between the two, rainfall is shown by a columnar diagram.[1]

Composite rainfall and relief profiles comprise another type of polygraph (Fig. 70); both rainfall and heights above sea-level are plotted as ordinates, using a common horizontal scale.

Comparative Percentage Graphs. Where climatic elements for a number of contrasting stations have to be compared, the mean annual totals may be reduced to a percentage basis to facilitate comparison, and plotted on the same graph.[2]

Durational graphs show variability in the duration of snowfall, length of growing season, etc., at different stations on the same frame. This technique may be applied, for example, to the study of seasonal duration of snow in an Alpine valley. Mean height of snow-lines for the

[1] The *Great Soviet World Atlas* (Moscow, 1938) has a series of such graphs, distinctively coloured, and related to a world-map of Köppen's climatic regions.

[2] W. G. Kendrew (*op. cit.*) makes frequent use of this device.

sunny (*adret*, *Sonnenseite*) and for the shady (*ubac*, *Schattenseite*) sides of the valley respectively, are plotted as ordinates, and months as abscissae.

Curve-parallels consist of superimposed graphs in series of related phenomena, for example, of rainfall with wind-run, relative humidity, vapour pressure and evaporation; curve parallels are also used to demonstrate similarities of climatic trends at different stations (Fig. 76).

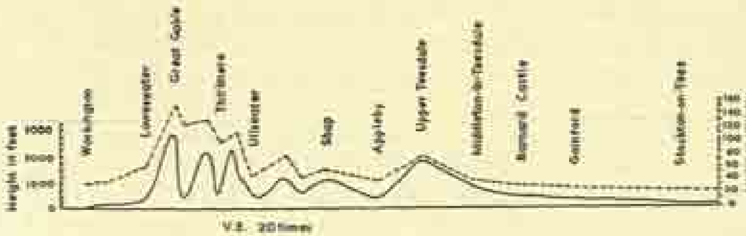


FIG. 70. COMPOSITE RAINFALL AND RELIEF PROFILE

The distance from Workington to Stockton is 90 miles.

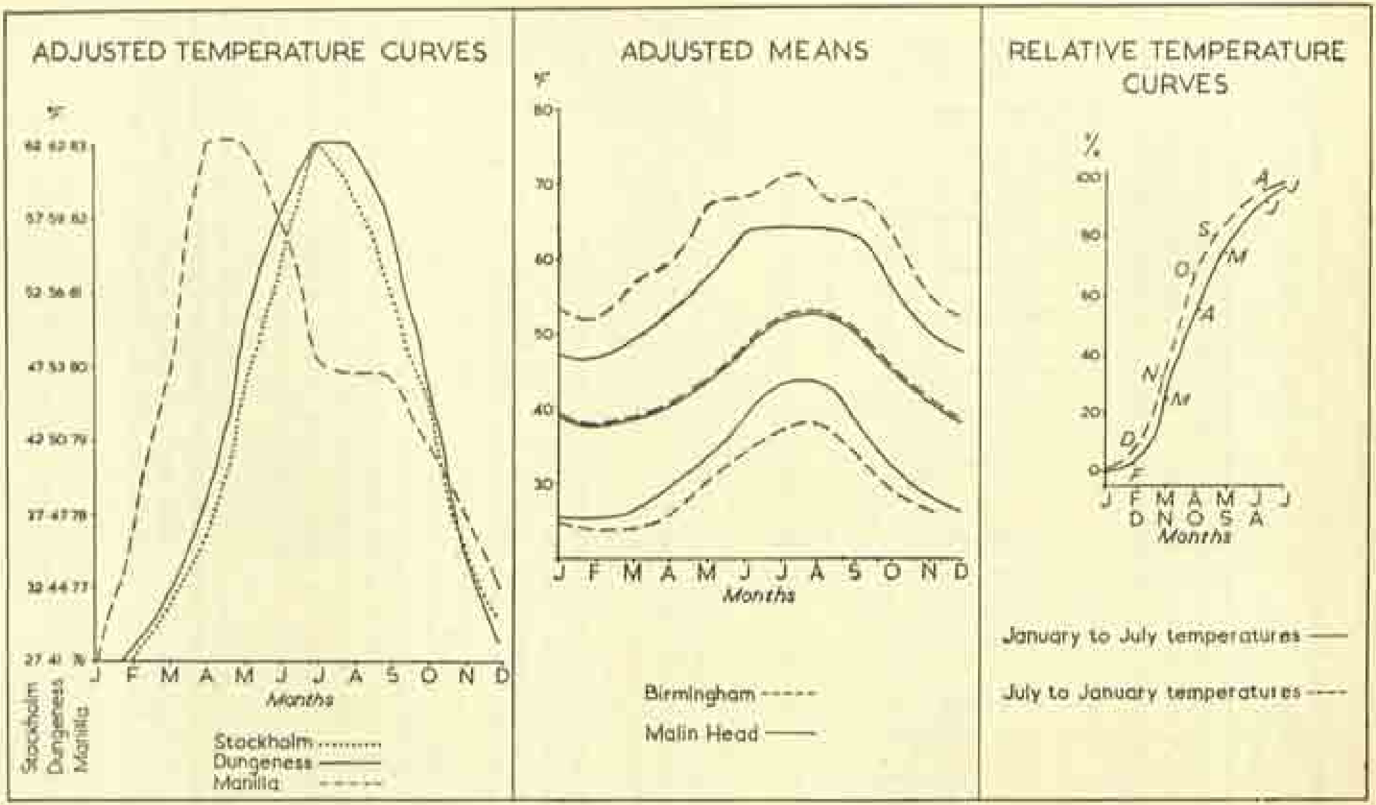
Adjusted Profiles. It may be profitable when studying regional variations in time-lag and in temperature variability to use temperature profiles, the shape of which is adjusted to make them directly comparable. One method of adjustment has been suggested by S. B. Jones in a study of the temperature regions of Hawaii.[1] This consists in reducing all temperature profiles to the same amplitude by adjusting the mean annual ranges of temperature to an equal size. Monthly and daily temperature profiles may be likewise reduced to the same amplitude. The adjusted profiles can then be placed one above another in a series or superimposed for comparative purposes (Fig. 71).

Diurnal and annual ranges of temperature may also be compared with the aid of adjusted profiles. For example, the mean monthly temperature curve of one station *X* can be made coincident with that for another *Y*, and the maxima and minima temperatures are then plotted; station *X* is plotted in the normal manner, but station *Y* in terms of deviations from the adjusted curve (Fig. 72).

A further method of facilitating comparison of temperature curves has been suggested by V. Conrad.[2] He made use of W. Köppen's concept of *relative temperatures* to produce a temperature curve in which the variations due to differences in the average temperatures and amplitudes at any two stations could be eliminated. The amounts by

[1] S. B. Jones, 'Lag and Ranges of Temperature in Hawaii', *Annals of the Association of American Geographers*, vol. 32 (Lancaster, Pa., 1942).

[2] V. Conrad, *Fundamentals of Physical Climatology* (Harvard, 1942).


ADJUSTED TEMPERATURE CURVES
°F
62 62 83
57 59 82
52 56 81
47 53 80
42 50 79
37 47 78
32 44 77
27 41 76
Stockholm
Dungeness
Manilla
J F M A M J J A S O N D
Months
Stockholm
Dungeness
Manilla
ADJUSTED MEANS
°F
80
70
60
50
40
30
J F M A M J J A S O N D
Months
Birmingham
Malin Head
RELATIVE TEMPERATURE CURVES
%
100
80
60
40
20
0
J F M A M J J
D N O S A
Months
January to July temperatures
July to January temperatures

which the consecutive monthly averages at any station exceed the temperature of the coldest month are expressed as percentages of the differences in average temperatures between the coldest and the warmest months. These values are then plotted as ordinates and the months as abscissae. The horizontal scale is so graduated as to enable the relative temperatures for the first six months of the year to be compared directly with those for the last six (Fig. 73).

Water surplus graphs are line-graphs showing the superimposition of the mean monthly evapo-transpiration and the mean monthly rainfall. Thus they constitute a valuable means of analysing local climate in terms of seasonal moisture surplus and rainfall efficiency (Fig. 74, and see also p. 131).

Sociographs. A number of ingenious graphical devices in the form of polygraphs have been evolved for the purpose of relating the seasonal rhythm of the climate to amount and nature of the work done in particular regions. L. Garrard has called these graphs *sociographs*.[1] Graps showing seasonal rhythm and cropping are of a similar nature.[2] Circular graphs are sometimes better fitted to carry this type of information (see pp. 204-5).

Trend-Graphs

The accurate determination of trends of climate is dependent upon the availability of reasonably complete and reliable records over a long period of time. The data have to be scrutinized, and corrections made for possible instrument error, for possible anomalies arising out of the location of the recording stations, and for possible error due to

[1] L. Gerrard, 'Sociographs of the Kulymans, Andamanese, etc.', *Studies in Regional Consciousness and Environment*, edited by I. C. Peate (Oxford, 1930). The paper includes a sociograph in which temperature curves, incidences of snow, floods, polar night, etc., are shown with reference to seasonal activities such as fishing, boat-making, marriage festivals, forest activities, and so on.

[2] A. Geddes, 'India: (1) The Chota Nagpur Plateau and its Bordering Plains', *Comptes Rendus du Congrès International de Géographie*, vol. 2, 3c (Amsterdam, 1938).

FIGS. 71–3. ADJUSTED TEMPERATURE PROFILES

Fig. 71 (left) shows three temperature curves adjusted to the same amplitude to facilitate comparison of the temperature regime.

Fig. 72 (centre) shows temperature conditions at two stations, Birmingham and Malin Head. The mean curve of one, Birmingham, has been made coincident with that of the Malin Head so that variability may better be compared.

Fig. 73 (right) shows relative temperature curves for Bismarck, N.D., and is based on V. Conrad, *Fundamentals of Physical Climatology* (Harvard, 1942). The amounts by which the consecutive monthly average temperatures exceed the temperature of the coldest month are each expressed as a percentage of the difference between the average temperature of the warmest and coldest months.

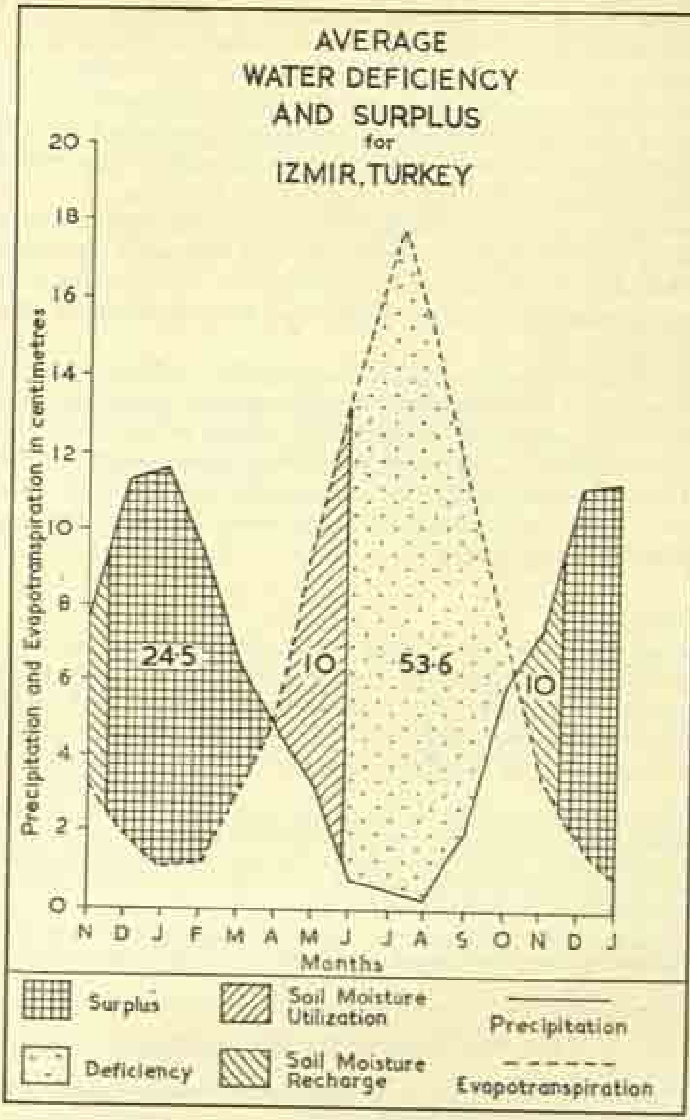


FIG. 74. A WATER-SURPLUS GRAPH

Based on S. Erinç, 'Climatic Types and Variation of Moisture Regions in Turkey', *Geographical Review*, vol. 40, p. 228 (New York, 1950).

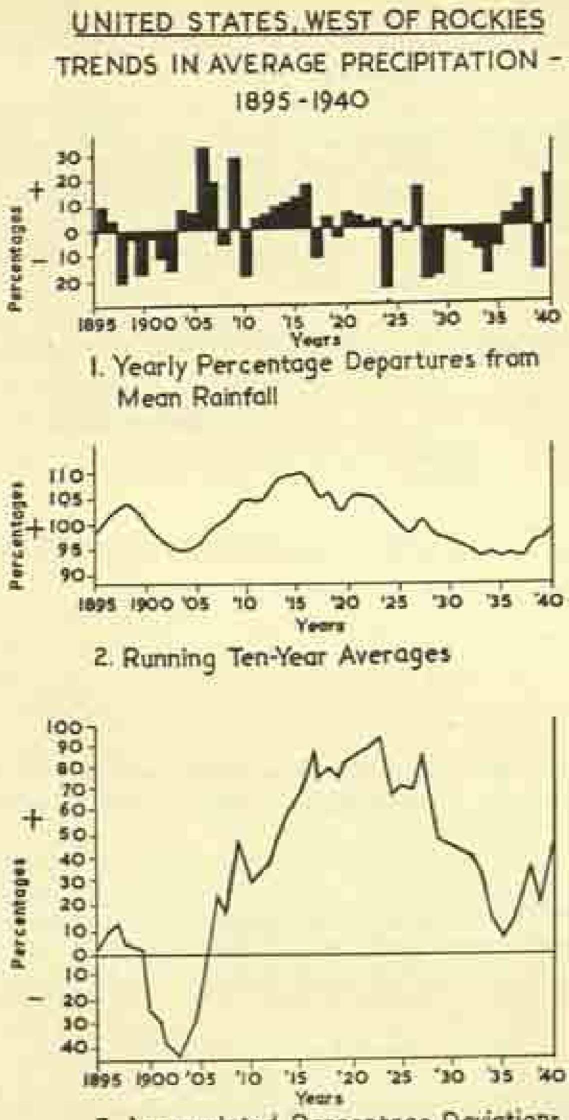


FIG. 75. GRAPHS OF RAINFALL TRENDS

1 and 2 are based on diagrams in United States Department of Agriculture, *Climate and Man* (Washington, 1941). The data used were average 'weighted' precipitations, the mean value of which was 17·9 inches. 3 has been drawn on the basis of the same data.

the faulty siting of instruments. Unless data are duly corrected for such errors the finished graphs will record variability in the observation of data rather than genuine trends.

Running Means. Trends in temperature and rainfall naturally attract the attention of the climatologist. Graphs, in which individual yearly means are plotted chronologically, are sufficient to show well-marked trends. But in order to smooth out fluctuations in the curves, running (or moving) means may be plotted, on either a three, a five, a ten or a twenty-year basis (Figs. 75–6). A method of calculating running means is given in the table below.

Calculation of Three-Year Running Means for Temperature (°F)

Date	*Annual Means*	*Running Means*					
		1		2		3	
1860	62·1	62·1					
1861	69·3	69·3	65·2	69·3			
1862	64·2	64·2		64·2	68·4	64·2	
1863	71·6			71·6		71·6	65·1
1864	59·4					59·4	

The running means are plotted to represent the midpoint of the three annual means, for example, 65·2 is plotted against 1861, 68·4 against 1862, 65·1 against 1863, and so on.

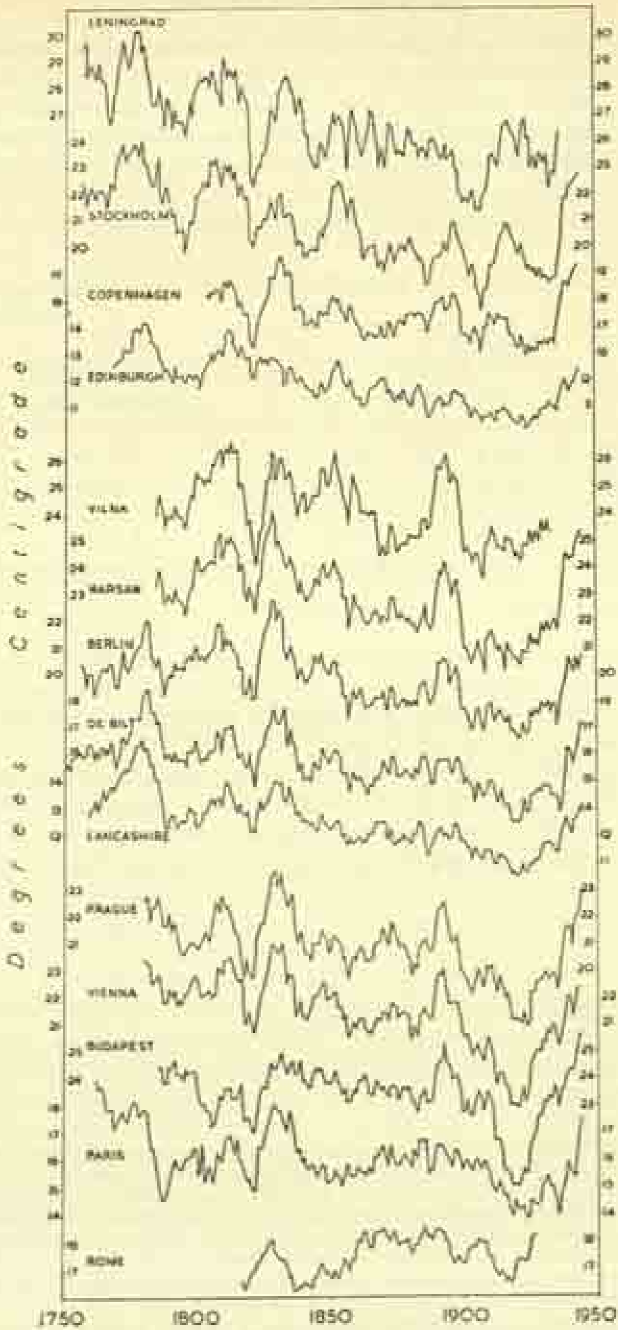
Curves to represent fluctuations in amplitudes of temperature over a period of years can also be smoothed out in this manner (Fig. 76).

Deviational Graphs. Cyclic fluctuations and trends in temperature and rainfall may be represented graphically by methods other than the

FIG. 76 CURVE PARALLELS OF TEMPERATURE

Based on I. A. Labrijn, *Onderzoek naar Klimaatsschommelingen in het Stroomgebied van de Rijn* (Amsterdam, 1948).

The graph shows variations in the amplitudes of temperature (i.e. differences between the mean July temperatures and those of the preceding January). Hence the curve for Stockholm indicates a tendency towards a decline in amplitude during the nineteenth century but a marked increase in recent years. Large amplitudes are usually associated with higher summer temperatures and colder winter conditions so that an increase in amplitude denotes a tendency towards greater extremes of climate. The strikingly close relationship between long-term temperature trends at different stations in Europe is clearly revealed by placing the curves in parallel.



Degrees Centigrade
LENINGRAD
STOCKHOLM
COPENHAGEN
EDINBURGH
VILNA
WARSAW
BERLIN
DE BILT
LANCASHIRE
PRAGUE
VIENNA
BUDAPEST
PARIS
ROME
1750
1800
1850
1900
1950

chronological plotting of mean values. Cumulative graphs are effective, for example, in showing cyclic fluctuations in rainfall.[1] For this type of graph, annual deviations from the mean annual rainfall or from base are obtained by subtraction, and the accumulated deviations by addition as follows:

Accumulated Deviations (Rainfall in Inches)

Year	*Rainfall*	*Mean Rainfall for the Series 1860–1940 =23·0 inches*	
		Deviation	*Accumulated Deviation*
1860	25·9	+2·9	+ 2·9
1861	30·4	+7·4	+10·3
1862	17·9	−5·1	+ 5·2
1863	24·6	+1·6	+ 6·8
1864	25·2	+2·2	+ 9·0

The accumulated deviations are then plotted, +2·9 against 1860, +10·3 against 1861, and so on. Cyclic fluctuations in rainfall for adjacent stations are easier to compare if the accumulated deviations are expressed as percentage (Fig. 75).

D. Brunt used a form of deviational graph which he called a *periodogram*, in connection with the determination of climatic cycles.[2] In this graph amplitudes of temperature in the form of deviations are plotted as ordinates and various periods of time as abscissae. Thus a periodogram for Stockholm derived from monthly temperature values for 100 years indicated a 13-month period as one with the largest amplitude.

Frequency Graphs

Graphs in which the frequency of extreme temperatures, droughts, spells of heavy rainfall, thunderstorms, characteristic types of weather and similar climatic phenomena is plotted are of great value to the

[1] See, for example, (*a*) C. B. Saville, 'Some Rainfall Variations, England and New England (U.S.A.)', *Quarterly Journal of the Royal Meteorological Society*, vol. 60 (London, 1933), for graphs of rainfall trends, 183-year series, by accumulated sums of departure from base; (*b*) Commonwealth of Australia Meteorological Bureau, *Bradfield Scheme for Watering the Inland—Meteorological Aspects* (Melbourne, 1945), for rainfall trends by accumulated deviation from mean; (*c*) R. W. Longley, 'The Variability of Mean Daily Temperature', *Quarterly Journal of the Royal Meteorological Society*, vol. 73 (London, 1947), for graphs of temperature by standard deviations.

[2] D. Brunt, 'Climatic Cycles', *Geographical Journal*, vol. 89 (London, 1937).

climatologist. They demonstrate aspects of climate which graphs of mean values may conceal, and they are of particular use in the delimitation of seasons.

A *histogram* is a diagram in which the frequency percentage of amounts of rain, for example, is plotted as ordinates and the amounts of rainfall as abscissae, and the peak of the curve represents the mean frequency. In practice, partly owing to limited data and partly in

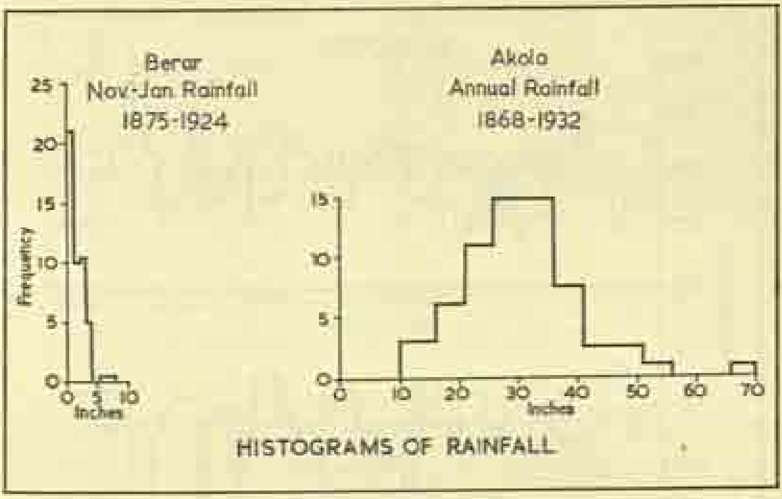


Fig. 77

Based on N. Carruthers, 'An Analysis of the Variations in Rainfall at Akola, Berar, Central India', *Geography*, vol. 30, p. 70 (London, 1945).

order to reduce the labour involved in their compilation, these graphs are reduced to step-diagrams by grouping values together (Fig. 77).

Seasonal Frequencies. Seasonal variations in frequency may be shown on a monthly as well as on an annual basis (Fig. 77). Superimposition of January and June frequencies, for example, suffices to show the contrast between summer and winter rainfall frequencies. Seasonal frequencies may also be shown by plotting the number of frequencies or percentage frequencies as ordinates and months as abscissae.[1] Frequency of long spells of weather, for example, may be grouped in this way (Fig. 68). It is sometimes useful when seasonal frequencies, for example, of types of weather, are being computed to invert the frequency curve

[1] Note A. T. Doodson and H. J. Bigelstone, 'The Frequency of the Distribution of Rainfall at Liverpool Observatory, Bidston', *Quarterly Journal of the Royal Meteorological Society*, vol. 60 (London, 1934), for analysis of rainfall based on frequency graphs.

for one station so that comparison of irregularities in the frequency curves of both stations is facilitated (Fig. 78).

Use of Logarithmic and Probability Graph-Paper. Either because of a very great range in frequency, or because of great ranges in the climatic data being plotted, it is advisable to use logarithmic or semi-logarithmic graph-paper for certain types of frequency graph. Particularly is this the case where pluviographic records of rainfall are

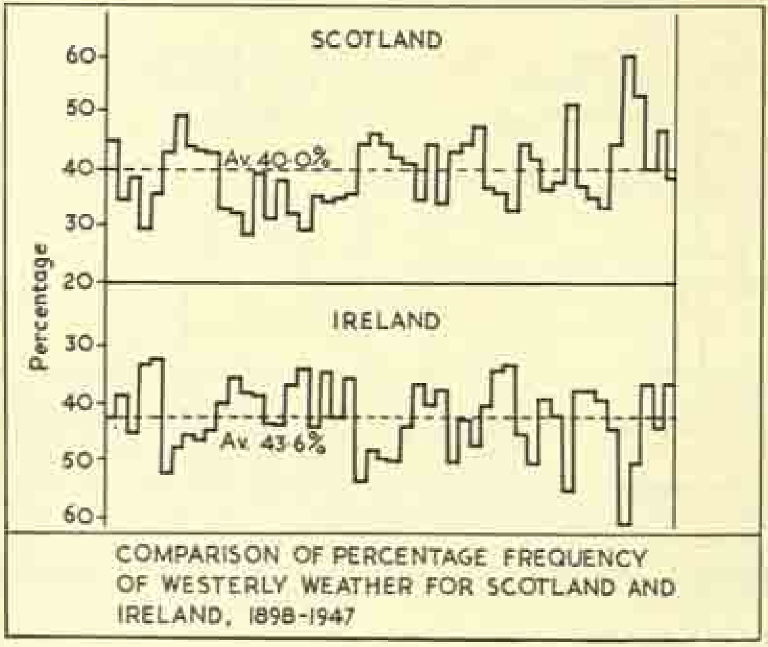


FIG. 78. A COMPARABLE FREQUENCY GRAPH

Based on R. B. M. Levick, 'Fifty Years of British Weather', *Weather*, vol. 5, No. 7, p. 247 (London, 1950).

being analysed upon a frequency basis (Fig. 79). Probability graph-paper also has its uses for this kind of work.

Circular Graphs

Circular graphs in which values of temperature, rainfall, wind, or of other elements, are plotted from a central origin along axes radiating outwards in different directions, the plotted points then being joined to form closed curves, have certain advantages over the conventional

Cartesian graph.[1] In the depiction of seasonal changes they show continuity from the end of one year through to the beginning of the next year which cannot be shown conventionally without duplication. The division of a circle through 360° nearly coincides with the

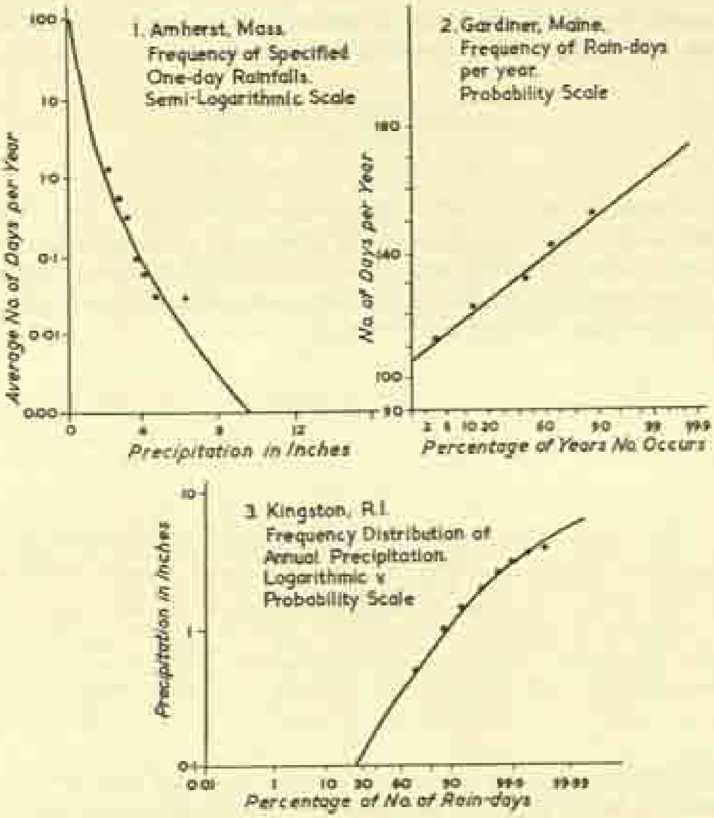


FIG. 79. VARIETIES OF RAINFALL FREQUENCY GRAPHS

Based on graphs in E. E. Foster, *Rainfall and Run-off* (New York, 1949). Note the use made of logarithmic and probability graph-paper.

division of a year into 365 days, and monthly data for most purposes may be depicted by intervals of about 30°. For more exact work monthly data have to be adjusted to represent 30 days. Circular percentage graph-paper may be used for specific types of data.

[1] Their possibilities were first discussed by S. Friedman, 'Graphische Darstellung der Jährlichen Temperatur eines Ortes durch geschlossene Curven', *Mitteilungen der k.-k. geographischen Gesellschaft in Wien*, vol. 6 (Vienna, 1862).

Climatographs. The climatograph devised by E. N. Munns[1] and elaborated by R. Hartshorne[2] provides a clear illustration of the use of circular graphs (Fig. 80). Mean monthly temperatures are plotted from a centre with the aid of a graduated table. The distance from the centre of the circle to 100°F is taken as ten times the distance from the centre to 0°F. If the latter difference is X, then the difference Y for any temperature t°F is given by the formula,

$$Y = X\frac{(Colog.\ t)}{100}$$

This formula is used in order that temperatures below zero can be plotted, and it has the advantage of producing a temperature curve the slope of which correctly represents the degree of change in temperature from month to month. The table given below allows values of *Colog. t*/100 to be interpolated with fair accuracy.

°F	110	105	100	95	90	85	80	75
Colog. t/100 .	12·59	11·72	10·0	8·91	7·94	7·08	6·31	5·62
°F	70	65	60	55	50	40	30	20
Colog. t/100 .	5·01	4·47	3·98	3·55	3·16	2·51	2·0	1·59
°F	10	0	−10	−20	−40	−60	−100	
Colog. t/100 .	1·26	1·00	0·79	0·63	0·40	0·25	0·10	

If the limiting temperatures of hot, warm, cool and cold seasons are assumed to be 68°F, 50°F, and 32°F, then the length and number of such seasons at any place may be read from the graph by noting where the temperature curve cuts the lines representing the limiting temperatures (Fig. 80).

Other methods of constructing circular graphs are discussed at length by J. B. Leighly.[3] Mention may be made of a compound cir-

[1] E. N. Munns, 'The Climatograph, a New Form of Chart for Climatic Phenomena', *Monthly Weather Review*, vol. 50 (Washington, 1922).

[2] R. Hartshorne, 'Six Standard Seasons of the Year', *Annals of the Association of American Geographers*, vol. 28 (Lancaster, Pa., 1938).

[3] J. B. Leighly, 'Graphic Studies in Climatology, II. The Polar Form of Diagram in the Plotting of the Annual Climatic Cycle', *University of California Publications in Geography*, vol. 2, no. 13 (Berkeley, 1929).

cular graph devised by him in which the distribution of rainfall is superimposed upon a temperature curve. The rainfall is depicted by columns which radiate outwards from the centre of the diagram.

Isopleth Graphs

In a graph of this nature the hourly values of pressure, temperature, etc., are plotted as abscissae and their time of occurrence in the month

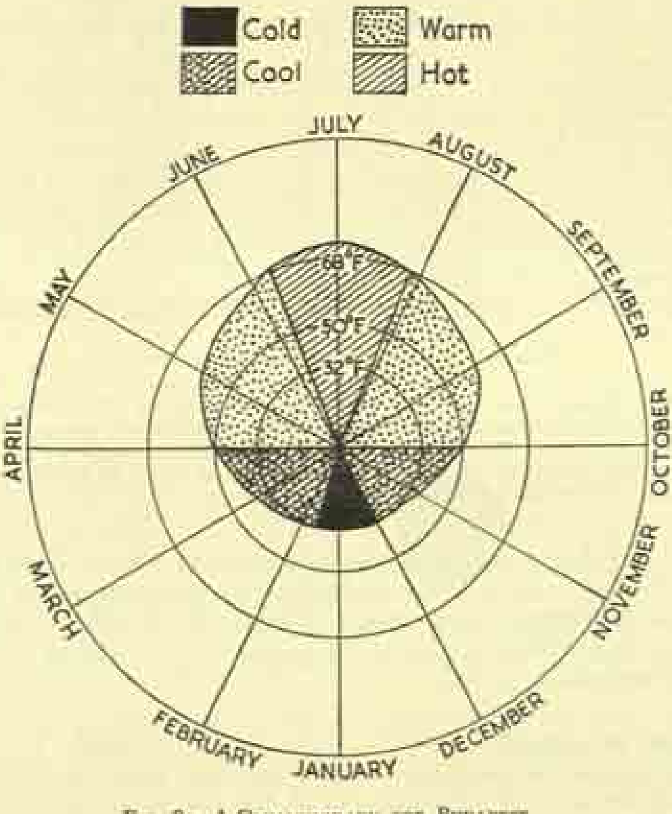


FIG. 80. A CLIMATOGRAPH FOR BUDAPEST

by ordinates. Similar values are then joined by isopleths. Sir Napier Shaw refers to these graphs as 'chrono-isopleth diagrams'.[1] The procedure is made clear in Fig. 81. Similar diagrams rather ponderously

[1] *Manual of Meteorology*, vol. 1 (Cambridge, 1926). Chapter 6 deals with the development of arithmetical and graphical manipulation of climatic statistics. The method is applied in, W. T. Gehrke, 'The Wind Flow Diagram', *Annals of the Association of American Geographers*, vol. 34 (Lancaster, Pa., 1944). Extensive use is made of this method in R. Geiger, *The Climate Near the Ground* (Harvard, 1950).

termed hypso-chrono-isopleths can be used to show variations of elements of the weather with both height and time.

Wind-Rose Diagrams

The wind-rose is a form of star-diagram which is peculiarly suited to show the average frequency and direction of wind at one place. In

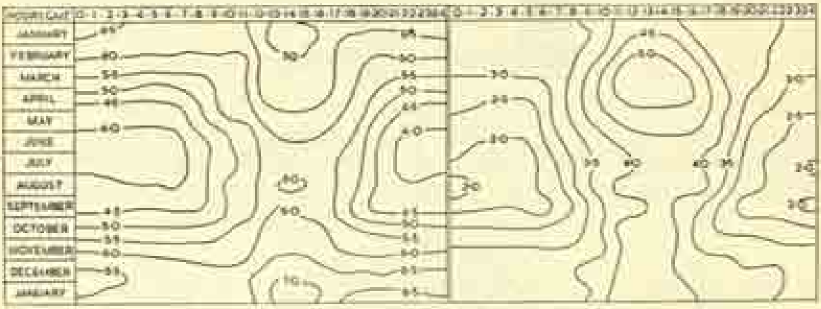


Fig. 81. Isopleth Graphs of Wind Speed

Based on Sir Napier Shaw, *Manual of Meteorology*, vol. 1, p. 267 (Cambridge, 1926).
The diagram shows mean wind speeds in metres per second at two stations, Valencia, Ireland (left-hand) and Kew, London (right-hand). The wind speeds are plotted for hourly periods, month by month. The interpolation of isopleths facilitates direct comparison of wind-speed conditions.

Fig. 82 a variety of types of wind-rose is depicted. Usually wind direction is defined in terms of the cardinal points, although ordinal points may be used where greater detail is required. All wind is assumed to come from the directions of the points selected. Calms are considered separately.

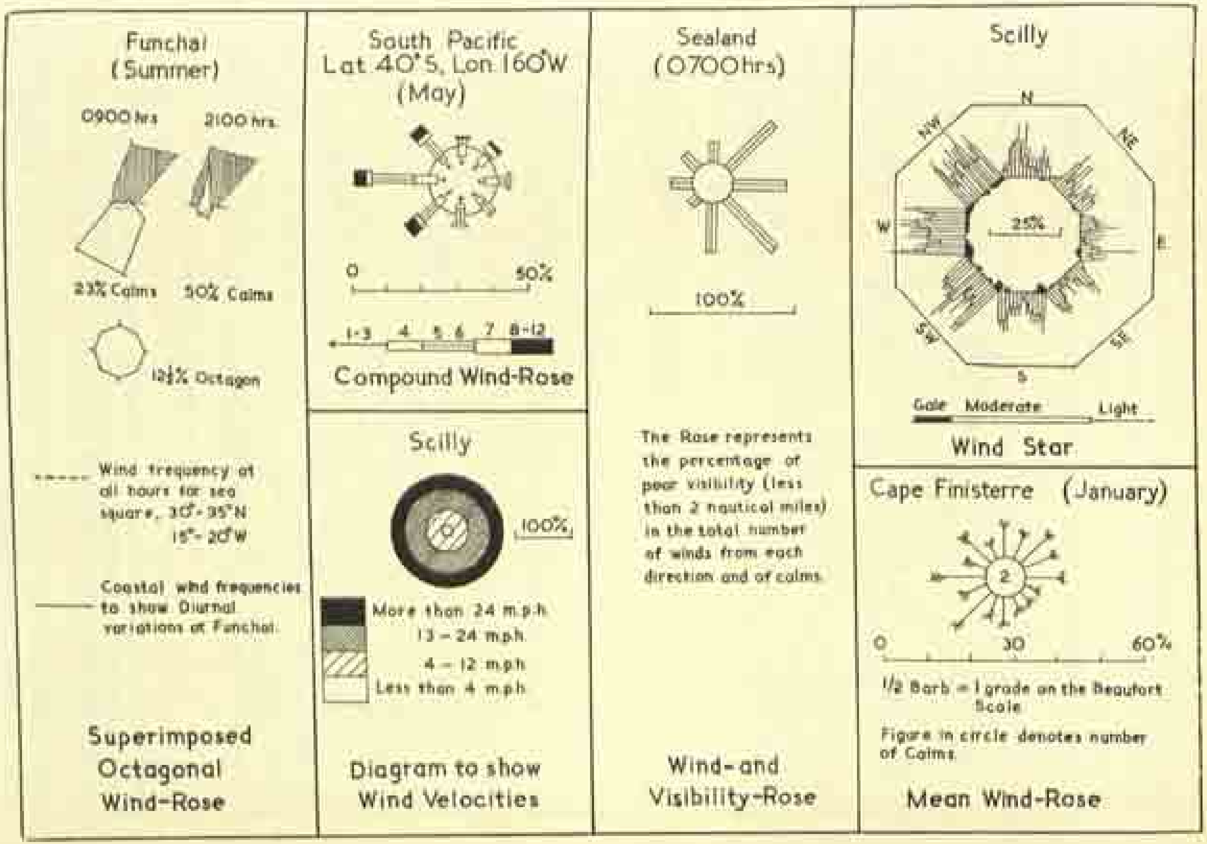
Octagonal Wind-Roses

This diagram is designed to reflect the total mean monthly conditions both of wind frequency and of direction at one station. Two concentric octagons are constructed, so that the distance between the

---

Fig. 82. Types of Wind-Rose and Wind-Speed Diagram

Particular examples have been drawn from the following sources: (1) Meteorological Office, *Weather in Home Waters and the North-eastern Atlantic*, vol. 2, pt. 1 (London, 1944) and pt. 4 (London, 1940); (2) E. G. Bilham, *Climate of the British Isles* (London, 1938); (3) Sir Napier Shaw and L. G. Garbett, 'A New Sort of Wind Rose', *Quarterly Journal of the Royal Meteorological Society*, vol. 59 (London, 1933).


Funchal
(Summer)
0900 hrs
2100 hrs.
23% Calms
50% Calms
12½% Octagon
Wind frequency at all hours for sea square, 30°-35°N 15°-20°W
Coastal wind frequencies to show Diurnal variations at Funchal.
Superimposed Octagonal Wind-Rose
South Pacific
Lat 40°S, Lon 160°W
(May)
0
50%
1-3
4
5
6
7
8-12
Compound Wind-Rose
Scilly
100%
More than 24 m.p.h.
13 – 24 m.p.h.
4 – 12 m.p.h.
Less than 4 m.p.h.
Diagram to show Wind Velocities
Sealand
(0700 hrs)
100%
The Rose represents the percentage of poor visibility (less than 2 nautical miles) in the total number of winds from each direction and of calms.
Wind-and Visibility-Rose
Scilly
N
NE
E
SE
S
SW
W
NW
25%
Gale
Moderate
Light
Wind Star
Cape Finisterre (January)
2
0
30
60%
½ Barb = 1 grade on the Beaufort Scale
Figure in circle denotes number of Calms.
Mean Wind-Rose

corresponding sides of each octagon represents a frequency of 12½ per cent. Each side represents one of the eight cardinal wind directions, and the twelve mean monthly frequencies of wind from each of these directions are plotted as columns, so that if winds were equally frequent from each direction, eight sets of twelve equal columns would result,

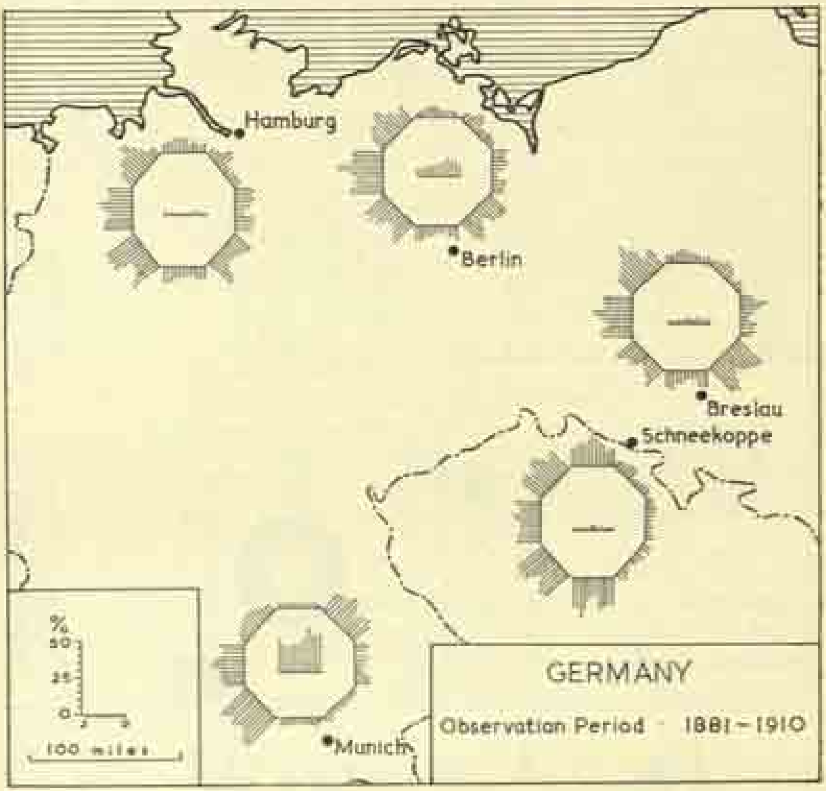


Fig. 83. Located Wind Roses

Based on E. Alt, 'Klimakunde von Mittel-und-Südeuropa', W. Köppen and R. Geiger, *Handbuch der Klimatologie*, vol. 3, pp. 203–4 (Berlin, 1938).
Calms are represented in the centre of each octagon.

each column having its base on the inner octagon and its apex on the outer octagon. Thus frequencies greater than average will be shown by columns extending over the outer polygon and vice versa. Calms are represented diagrammatically within the centre of the inner octagon (Fig. 83).

Simple Wind-Roses

Octagonal wind-roses are difficult to interpret and the conditions they represent may be shown more simply by twelve diagrams, each representing the conditions for one month. Two concentric circles, the circumferences of which are set at a distance representing 12½ per cent, are drawn, and columns representing the percentage frequency of wind from each of eight directions are plotted upon this basis; the percentage frequency of calms is indicated by a number placed within the smaller circle. Average annual frequencies of wind from each direction may also be depicted by this method when seasonal variations are not required.

Compound Wind-Roses

Wind-rose columns indicating frequency may be subdivided to show the frequency of wind strengths associated with the particular direction represented (Fig. 82). Four divisions indicating the following velocities respectively are usually sufficient for most purposes:

1. *More than* 24 *m.p.h.*
2. 13 *to* 24 *m.p.h.*
3. 4 *to* 12 *m.p.h.*
4. *Less than* 4 *m.p.h.*

Wind-roses of this type are frequently employed in the analysis of upper winds, the velocities of which are much stronger than those of surface winds.

Superimposed Wind-Roses

The idea of wind-roses may be adopted for the purpose of showing unusual diurnal variations of wind. For example, to demonstrate changing directions of wind between day and night at any place, wind-roses, each representing mean conditions at different times of observation during the day, may be superimposed (Fig. 82). In this case, for the sake of clarity, frequencies are plotted from a central point and joined to form irregular octagons.

Wind- and Visibility-Roses

Relationships between visibility and wind direction may be expressed in the form of wind-roses. Observations are often made at the same time, so that frequencies of bad and good visibilities may be correlated with wind direction. The percentage frequency of bad visibility, for example, may then be plotted for different wind directions to form a rose (Fig. 82).

Wind-Stars

Wind-roses constructed to show monthly frequencies of wind from the sixteen ordinal directions, together with mean velocities, have been

termed *wind-stars* (Fig. 82).[1] These stars are ingeniously devised, but they are rather laborious to construct. Moreover, they do not reduce very well and they cannot be located on a base-map to show regional variations.

Rainfall Dispersion Diagrams

In recent years rainfall dispersion diagrams have become an important tool in the analysis of rainfall distribution. The median and other percentile values derived from the diagrams have greater significance in some cases than mean values, or than coefficients derived from mean values, in arriving at a more rational estimation of rainfall variability, and of classifying rainfall regimes.[2]

Construction of the Diagram

Diagrams may be made of the dispersion of annual amounts of rainfall for any one station simply by plotting dots of suitable size, each of which represents one year's rainfall, against a vertical scale uniformly graduated so that the base is zero and the top is equivalent to the maximum rainfall total (Fig. 84).[3] It is not advisable to attempt analysis unless at least a thirty-five year record of rainfall is available.

Annual dispersion graphs have only a limited value; of greater significance are monthly diagrams. For these, the vertical scale is graduated from zero to the highest monthly rainfall in the series. Monthly values are then plotted to give the individual rainfall dispersion for each month in the year (Fig. 84).

Median and Percentile Values

The median or middle value of rainfall for any dispersion diagram is that which lies midway between the two extremes of rainfall at either end of the diagram. Thus for a thirty-five year series the eighteenth value reckoned from the minimum is the median value. The lower quartile value is that which lies midway between the

[1] Sir Napier Shaw and L. G. Garbett, 'A New Sort of Wind Rose', *Quarterly Journal of the Royal Meteorological Society*, vol. 59 (London, 1933).

[2] For a discussion of the value of the median see American Geographical Union, 1940 Committee, 'Report of Committee on Median v. Arithmetical Average', *Transactions of the American Geographical Union*, Pt. 1 (Washington, 1941). See also an interesting graphic comparison of the distribution of rainfall as computed by means of the coefficient of variability, and as actually revealed by a dispersion diagram in E. E. Lackey, 'Annual Variability Rainfall Maps of the Great Plains', *Geographical Review*, vol. 27 (New York, 1937).

[3] The idea of applying dispersion diagrams to rainfall analysis was conceived by P. R. Crowe, 'The Analysis of Rainfall Probability', *Scottish Geographical Magazine*, vol. 49 (Edinburgh, 1933); and 'The Rainfall of the Western Plains, *Geographical Review*, vol. 26 (New York, 1936). See also H. A. Matthews, 'A New View of Some Familiar Indian Rainfalls', *Scottish Geographical Magazine*, vol. 52 (Edinburgh, 1936).

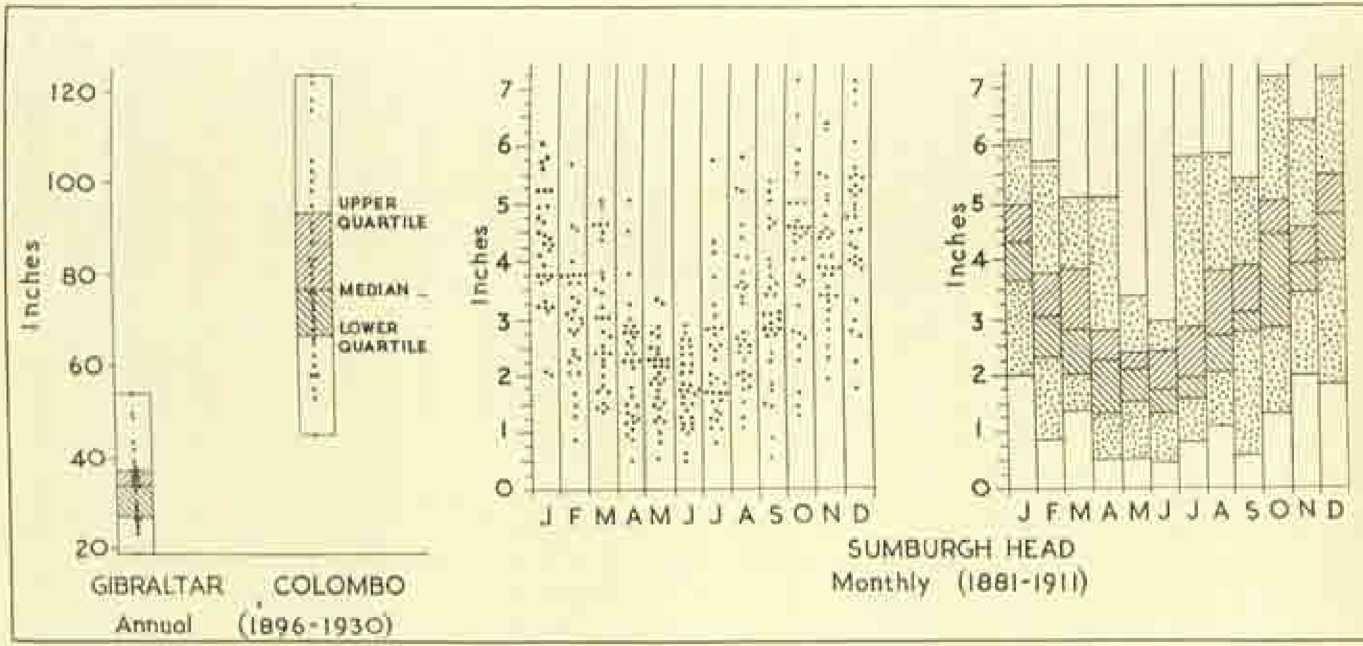


Fig. 84. Rainfall Dispersion Diagrams

The data for the left-hand diagram were derived from *World Weather Records*, Smithsonian Miscellaneous Collections, vols. 79 and 90. The inter-quartile ranges have been distinctively shaded.

The middle diagram is based on *Great Britain, Rainfall, Annual Average, 1881–1915* (Ordnance Survey, 1949).

The right-hand diagram is drawn from the same data but only the percentile range, the median and the quartile values are indicated by means of columns shaded for the purpose of comparison.

median and the minimum, i.e. in the above case it will lie halfway between the ninth and tenth figures reckoned from the minimum on the diagram. Similarly, the upper quartile value will lie between the ninth and tenth value reckoned from the maximum on the diagram. These values may be marked on the diagram by short horizontal lines (Fig. 84). Half the recorded values in the series will thus lie between the upper and lower quartile values.

Major, Minor and Graded Breaks

Discontinuities in rainfall at any one station may be estimated from an inspection of the relative positions of quartile and mean values for adjacent months. If the interquartile band of one month is clear of that for an adjacent month, a *major break* in rainfall is generally indicated. The month with the upper band will on an average be wetter than that with the lower band. The chances that the latter will be wetter are only one in eight. *Minor breaks* which mark semi-discontinuities are said to exist if the median and lower quartile of one month lie above the upper quartile and the median respectively of an adjacent month. If these conditions are satisfied for alternate instead of for adjacent months, a *graded break*, major or minor as the case may be, is said to exist. Discontinuities in rainfall regimes, as indicated by breaks, may be mapped with the aid of isopleths.

Merits and Demerits

Dispersion graphs are easy to construct. They show at a glance the dispersion of rainfall for any one station; they give an indication of seasonal distribution and actual variability without the necessity of making lengthy statistical calculations. The median value, as far as rainfall is concerned, has many advantages over the mean value, since the latter may give a false impression. Particularly is this so for places with a dry season. On the other hand, some disadvantages of the dispersion diagram have been pointed out by W. H. Hogg,[1] who drew attention to the fact that discontinuities for the same pair of adjacent months is not always a satisfactory criterion for distinguishing between rainfall zones, and that median values of rainfall cannot be validly used on a percentage basis because the twelve monthly medians of any station do not add up to the annual median.

CLIMOGRAPHS

A climograph (or climogram) is a diagram in which the data for elements of climate at any one station are plotted against one another, and the shape and position of the resultant graph provides an index

[1] W. H. Hogg, 'Rainfall Dispersion Diagrams', *Geography*, vol. 33 (London, 1948).

to the general climatic character of the place.[1] Usually a number of such diagrams is plotted on one chart for comparative purposes. The diagrams may be used to summarize variations in world climatic conditions, and they were used in this connection by W. Köppen.[2] He devised a chart in which temperatures of the coldest month were plotted as abscissae and temperatures of the warmest month as ordinates. The framework of the chart was subdivided to indicate the relative positions of tropical, mesothermal, boreal and tundra climates, etc.

J. B. Leighly's Climographs

J. B. Leighly expanded on Köppen's ideas to produce a number of climographs which could be used for comparison of the climates of different parts of the world.[3] These included one based on Köppen for analysing temperature. Another was specifically designed to record critical values of temperature and rainfall with regard to soil moisture conditions. The framework of this chart was graduated horizontally in °F and vertically in inches of rainfall, so that mean annual temperature could be plotted as abscissae and mean annual rainfall as ordinates. As a further refinement critical axes, derived from formulae which took into account various regimes of the distribution of rainfall in the definition of dry climates, were added to the chart.

Further graphs were constructed to enable subdivision of rain or forest climates to be made according to seasonal distribution of rainfall. In one of these graphs the rainfall of the driest month was plotted against the annual rainfall to indicate the presence of a dry season, and in a second, to illustrate seasonal contrasts in rainfall regime, maximum rainfall was plotted against minimum rainfall on an appropriate axis according to season of occurrence.

G. Taylor's Climographs

Climographs may be adapted to show the influence of climatic conditions on human activity. G. Taylor, for example, has used climographs for this purpose. In one of his climographs he indicates the physiological effects of climate on man by plotting relative-humidity values in relation to wet-bulb temperatures. The framework of the chart consists of a graduated vertical side-scale showing wet-bulb temperatures from −10°F to 90°F, and a horizontal bottom-scale

[1] This type of diagram was first conceived by J. Ball, 'Climatological Diagrams', *Cairo Scientific Journal*, vol. 4 (Cairo, 1910).

[2] W. Köppen, 'Klassifikation der Klimate nach Temperatur, Niederschlag und Jahrslauf', *Petermann's Geographische Mitteilungen*, vol. 64 (Gotha, 1918).

[3] J. B. Leighly, 'Graphic Studies in Climatology. I. Graphic Representations of a Classification of Climates', *University of California, Publications in Geography*, vol. 2, no. 3 (Berkeley, 1926).

showing percentage relative humidity from 20 to 100 per cent. The north-west corner of the chart he marked as *Scorching* (high wet-bulb, low relative humidity), the north-east corner as *Muggy* (high wet-bulb, high relative humidity), the south-west as *Keen* (low wet-bulb, low relative humidity), and the south-east as *Raw* (low wet-bulb, high relative humidity). The mean monthly data are plotted on this chart for a particular station, each month being marked by a letter, and the plotting points are then joined.[1] For a variation on this type of climograph, see Fig. 85.

The Hythergraph is another type of climograph used by G. Taylor, in which mean monthly temperature values are plotted as ordinates and mean monthly rainfall values as abscissae.[2] They are principally used in summarizing broad climatic differences in relation to human activity, more particularly with reference to settlement.

E. E. Foster's Climograph

E. E. Foster has devised a climograph (Fig. 87) with the aid of Thornthwaite's scheme of climatic classification (see p. 132).[3] This consists of a chart formed by a grid system of rectangular co-ordinates. The vertical side-scales are graduated from −20°F to 100°F, the horizontal bottom-scale from 0 to 18 inches of rainfall. The chart consists of six temperature zones, *Frigid* (−20°F to 0°F), *Cold* (0°F to 32°F), *Cool* (32°F to 50°F), *Mild* (50°F to 65°F), *Warm* (65°F to 80°F) and *Hot* (over 80°F). The Cool, Mild, Warm and Hot divisions are further subdivided into *Arid* (limiting grid points, 32·4°F, 0·32 inch of rain; 83·2°F, 1·03 inch of rain); *Semi-arid* (limiting grid points, 32·4°F, 0·59 inch; 83·2°F, 1·93 inch); *Subhumid* (limiting grid points, 32·4°F, 1·10 inch; 83·2°F, 3·6 inch); *Humid* (limiting grid points, 32·4°F, 2·05 inch; 83·2°F, 6·73 inch).

Special Climographs

Climographs may be used to demonstrate special aspects of climatic differentiation—for example, economic aspects by plotting length of growing season in hours per month against effective rainfall. They may even be adapted for showing the relationships between climate and soil-type (Fig. 86).

Arrows

Arrows are used conventionally to show the horizontal movement of air over the surface of the earth. They may be used either to show the

[1] For an example, see A. A. Miller, *Climatology* (London, 1942).

[2] See examples in G. Taylor, *Urban Geography* (London, 1949).

[3] E. E. Foster, 'A Descriptive Graph of Climate', *Transactions of the American Geographical Union*, part II (Washington, 1944).

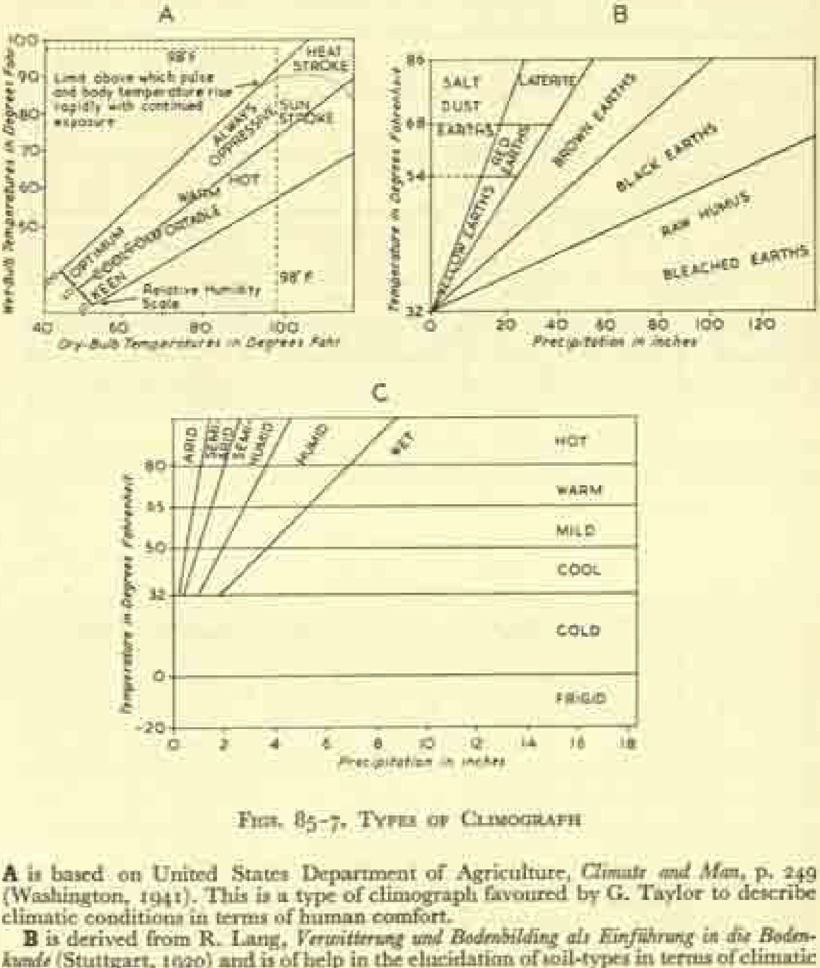


FIG. 85–7. TYPES OF CLIMOGRAPH

A is based on United States Department of Agriculture, *Climate and Man*, p. 249 (Washington, 1941). This is a type of climograph favoured by G. Taylor to describe climatic conditions in terms of human comfort.

B is derived from R. Lang, *Verwitterung und Bodenbildung als Einführung in die Bodenkunde* (Stuttgart, 1920) and is of help in the elucidation of soil-types in terms of climatic conditions.

C is based on E. E. Foster, *Rainfall and Runoff* (New York, 1949). It makes use of Thornthwaite's formula and is designed to illustrate his system of climatic classification.

In the case of diagrams **A** and **C** monthly values are plotted and joined by a line, but only annual values are required in the case of Lang's climograph.

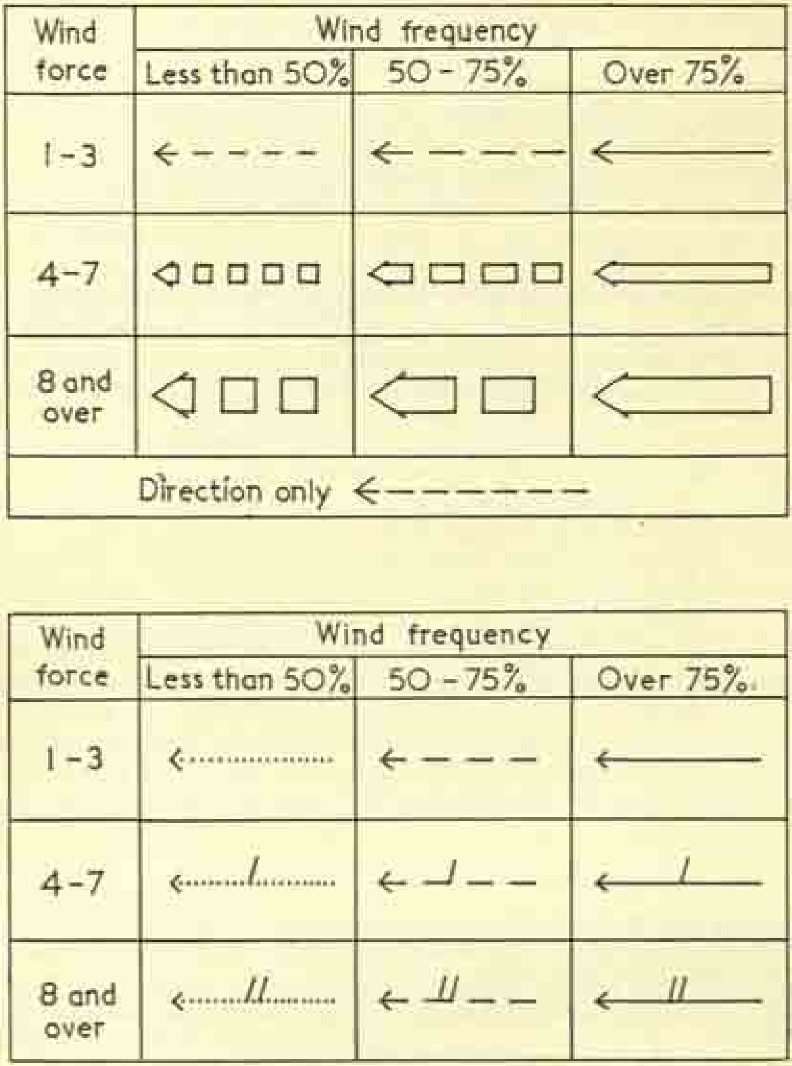


FIG. 88. ARROW SYSTEMS

Various systems for showing the distribution of wind direction and speed can be devised and the two given above, exaggerated for the sake of clarity, are only meant to serve as examples.

trajectories[1] of air or, more frequently, wind direction and direction of streams of air.

Wind systems, either planetary or local, can be depicted quite simply by short arrows, 'flying with the wind', and indicating prevailing wind directions at different times of the year. They may be drawn by inference from mean isobars and are not necessarily based on tabulated observations.[2]

Where observations are available, the frequency and force of such winds may roughly be indicated by thickening the shaft of the arrows according to average wind-force and by pecking the shaft of the arrow to show frequency. Alternatively, a system of tail-feathers and of differential shafts may be employed (Fig. 88).[3]

On synoptic charts, where wind conditions at a particular time have to be plotted, frequency is not required. Wind direction, therefore, is shown by point-tipped arrows, or arrows flying into the station symbols, the tails of which indicate wind-force by means of the number of feathers they carry.[4]

Climate is associated more with the typical movement of various types of air-mass from specific regions than with surface winds pure and simple. The plotting of average surface winds by means of arrows has its uses in the local differentiation of climate, but has little value in the analysis of the fundamental causes of climatic phenomena. A close study of the chronological sequence and average frequency of isobaric patterns and their associated weather conditions affords one method of determining the source and type of air-mass at any one place. Such analyses are properly undertaken by the professional weather forecaster, and findings are plotted by marking the hypothetical source regions of characteristic air-masses and by using arrows to indicate the generalized movement of air from such source regions.[5]

The mean movement of air, representative of different seasons, can be shown by *streamlines*, which take the form of elongated arrows curving to denote changes in direction (Fig. 89). Streamlines are usually drawn to resultant winds (see p. 116) at *gradient level*, which is at about 500 metres above the surface. Streamlines can be drawn to surface

[1] See a map after G. I. Taylor, in H. B. Byers, *General Meteorology* (New York, 1944), showing the computed trajectory of air in the vicinity of the Grand Banks, July 16–25, 1913.

[2] Given the pressure conditions, the computation of wind directions and wind speeds involves elaborate calculations demanding some knowledge of thermodynamics. Rule-of-thumb formulae may, however, be employed, and these are discussed at length in H. B. Byers, *General Meteorology* (New York, 1944), and S. Petterssen, *op. cit.*

[3] For an application, see Meteorological Office, *A Barometer Manual*, plates 7 and 8 (11th edition, London, 1932).

[4] For scale of velocities, see Meteorological Office, *The Weather Map*, 3rd edition (London, reprinted, 1950).

[5] For such maps, see S. Petterssen, *op. cit.*

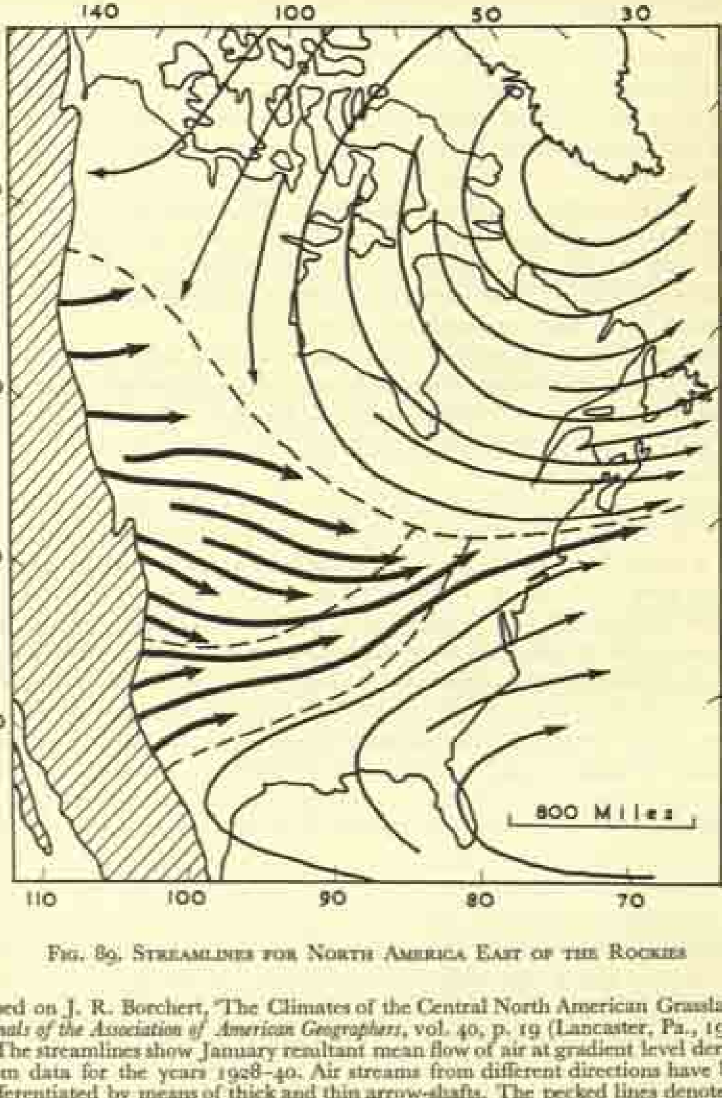


FIG. 89. STREAMLINES FOR NORTH AMERICA EAST OF THE ROCKIES

Based on J. R. Borchert, 'The Climates of the Central North American Grassland', *Annals of the Association of American Geographers*, vol. 40, p. 19 (Lancaster, Pa., 1950).

The streamlines show January resultant mean flow of air at gradient level derived from data for the years 1928–40. Air streams from different directions have been differentiated by means of thick and thin arrow-shafts. The pecked lines denote the axial belts of maximum occurrence of low-pressure centres recorded on the January (*Principal*) *Surface Weather Map* (Weather Bureau, Washington, D.C.). The data are conveniently extracted from manuscript maps which incorporate the number of low-pressure centres according to the daily weather map (0730 hours, Eastern Standard Time). The records are based on some 420 areas of 3,000 square miles each, covering North America and adjacent waters, 1930–9.

winds, but since turbulence at the surface due to friction is so great, and also because direction of wind varies according to local obstructions, the findings are not likely to be significant. Streamlines for very high altitudes can also be constructed, but they have not the same significance, from the point of view of life and activity on the surface as the 500-metre streamlines.[1] Also, pilot-balloon observations are fairly frequent and reasonably accurate at about 500 metres, whereas above that height both inaccuracy increases and observations are lacking.

In Fig. 89 streamlines based on resultant winds for January at gradient level reveal a strong westerly circulation over the greater part of the continent, but three distinctive air streams enter into its composition—a dry continental air stream from the base of the Rockies, a warm moist airstream from the sub-tropical Atlantic, and a cold one from the Arctic. The different origins of these air streams account for many peculiarities in the climate of parts of the North American continent.[2]

As J. R. Borchert emphasizes in his paper, the drawing of streamlines to resultant winds is a most valuable method of climatic analysis, but has been so far comparatively neglected. It must be pointed out, however, that some of the pioneers in the fields of dynamic meteorology advocated analyses along these lines many years ago.[3]

To illustrate relationships between streams of air at different altitudes and the weather conditions on the surface, three-dimensional sketches may serve a useful purpose, although, of course, it is necessary to resort to simplification and generalization (Fig. 90).

A further use of arrows is to depict the tracks of depressions and storm-paths. These are marked usually by elongated arrows which follow the average direction of movement of the centres of the depressions under consideration. The data are extracted from a series of synoptic charts covering the region concerned.[4] The speed of movement may also be indicated by dots placed along the arrows to represent intervals of time, and it is often the practice to plot a whole series of tracks covering a season, or even a number of years (Fig. 91). From such diagrams it is possible to produce generalized tracks representing mean conditions of movement. Some idea of the frequency with which cyclones follow particular paths may be given by elongated

[1] See a series of maps showing resultant wind directions at different altitudes in H. R. Byers, *op. cit.*

[2] J. R. Borchert, 'The Climate of the Central North American Grassland', *Annals of the Association of American Geographers*, vol. 40 (Lancaster, Pa., 1950).

[3] J. W. Sandström, *Dynamic Meteorology and Hydrography*, vol. 2 (Washington, 1910), for example, discusses graphical methods of constructing streamlines.

[4] M. A. Garbell (*op. cit.*) has an excellent arrow-map showing the general geographical distribution of tropical cyclones.

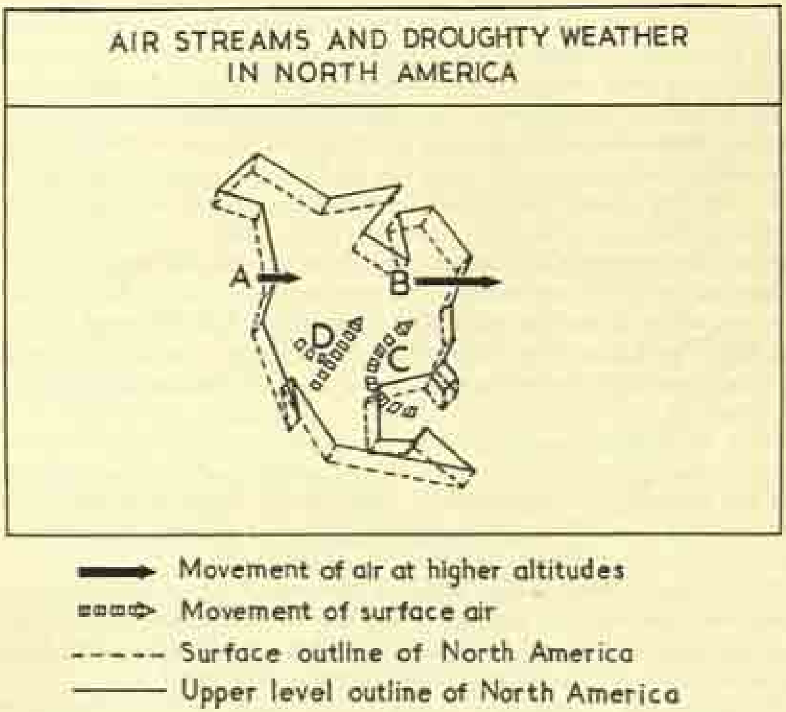


FIG. 90. A THREE-DIMENSIONAL SKETCH OF AIR STREAMS

Based on I. R. Tannehill, *Drought, its Causes and Effects*, p. 94 (London, 1947).

The diagram shows the main components of air currents over North America during times of drought. On the left the short arrow, **A**, indicates slow movement of air into the continent due to the relative warmth of the continent. The long arrow, **B**, indicates rapid movement of air out of the continent towards the relatively cool Atlantic. Arrow **C** shows surface rain-bearing air flowing into the continent to make up for the inequality of components **A** and **B**. This surface air may normally bring rainfall into the central plains. If, however, the inequality between **A** and **B** is too great, dry surface air will be drawn into the continent from the direction of the Mexican plateau —arrow **D**. Air current **C** will then be deflected north-eastwards and the interior plains will suffer drought as a result. There is little or no surface air coming in from Canada during this period. It is of interest to compare this diagram with Fig. 89.

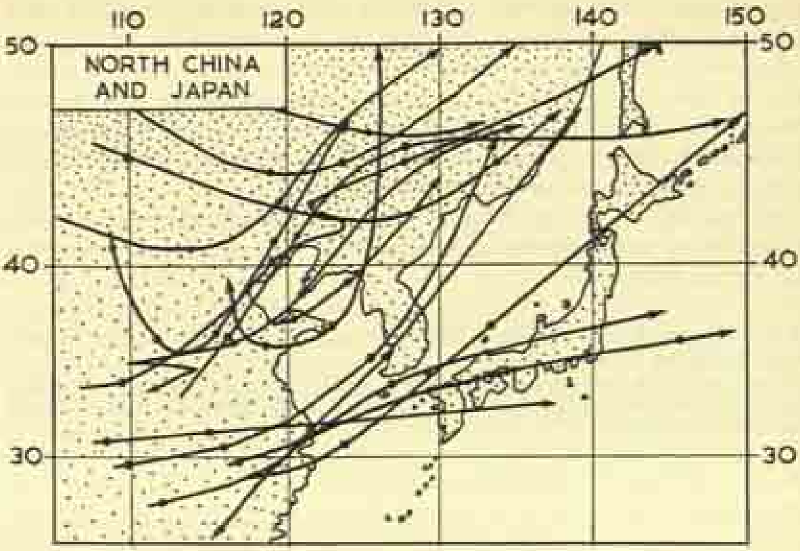


FIG. 91. TRACKS OF CYCLONIC DEPRESSIONS, JULY

Based on Meteorological Office, *Weather in the China Seas and in the Western Part of the North Pacific Ocean*, vol. 1, pt. 1, p. 48 (London, 1938).

The tracks are taken from the annual charts published by the observatory at Zikawei, and have been amplified in northerly regions by reference to the synoptic charts published by the Meteorological Services of Nanking and Tokyo. The black dots on the tracks mark the successive positions of centres of depressions as identified from consecutive synoptic charts. The distance apart between two dots in the same track is thus equal to the distance travelled by any particular depression in 24 hours. The data used refer to the five years 1929–31 and 1933–4.

arrows, the shaft-thicknesses of which are made proportional to the number of occasions cyclones have taken the routes indicated.[1]

SYMBOLS

Symbols are used chiefly in the plotting of weather data on synoptic charts.[2] They may also be used to show the distribution of various types of weather-station, according to reliability, and according to the nature of function.

Proportional symbols may be specially adapted to show distributions of weather and climate. Proportional squares, for example, may be effectively employed to show the distribution of rainfall associated with the passage of a depression. The squares are made

[1] See an example in W. G. Kendrew, *Climatology*, p. 342 (Oxford, 1949).

[2] For details consult *The Weather Map* (*op. cit.*), and *The International Meteorological Code* (*op. cit.*).

proportional to the amount of rainfall at the particular places, and may be shaded according to the time, or duration of the fall.[1]

Proportional circles are occasionally used to show regional variations in mean wind velocities. Uniform circles are drawn divided into concentric circles, so that circular bands of varying thickness are shaded to represent percentage frequencies of winds of more than 24 m.p.h., 12 to 24, 4 to 12, and under 4 m.p.h. (Fig. 82).

Symbols are also used to show distribution of freak weather over a number of years—heavy thunderstorms, record rainfall intensities and record droughts.[2]

[1] See a map by J. H. G. Lebon, 'The Interpretation of the Daily Weather Report', *Geography*, vol. 32 (London, 1947).

[2] For a map utilizing such symbols, see S. S. Visher, 'Regionalization of the United States on a Precipitation Basis', *Annals of the Association of American Geographers*, vol. 32 (Lancaster, Pa., 1942).

CHAPTER IV

ECONOMIC MAPS AND DIAGRAMS

THE economic geographer is concerned with the spacial distributions and inter-relations of various forms of economic activity, which involve primarily a study of the production, distribution and consumption of commodities in their regional settings. The geographical relationships of the distributions, forms and patterns thus involved lend themselves to a wide range of cartographical representation. As V. C. Finch wrote: "No other of the social studies than economic geography insists upon so rich a symbolization of its facts and concepts in cartographic form."[1] Many of the methods used must of course conform to certain cartographical conventions, but the economic geographer can frequently devize modifications of method or even wholly original presentations of his data. In view of the manifold possibilities, it must be realized that the methods discussed in this chapter and the maps and diagrams used in illustration are, perhaps even more than usual, merely examples and suggestions.

DATA

With the exception of maps of simple areal distributions, most economic maps and diagrams involve some precise depiction of amounts, values, areas, ratios, distances and rates, and their compilation necessitates the handling of much statistical material. In fact, the economic geographer finds that such data form the major part of his sources; from them he selects his factual information, presents his analysis, and draws his conclusions. So he assembles and tabulates his data, considers the cartographical method most suited to the problem involved—whether isopleth map, choropleth map, dot map, graph or diagram—and then converts his tables into the chosen medium.

Available Sources

The available statistical sources may be described under four heads. These comprise international publications, produced by such agencies as the former League of Nations or the United Nations Organization, official government publications, other published information, and a vast amount of unpublished material.

International Publications. International agencies are able to collect,

[1] V. C. Finch, 'Training for Research in Economic Geography', *Annals of the Association of American Geographers*, vol. 34, p. 213 (Lancaster, Pa., 1944).

compile and publish statistics in a very convenient form for the economic geographer. Between the wars, the Economic Intelligence Service of the League of Nations produced some very valuable statistical summaries. Its base-volume was the *Statistical Year-Book*, which gave figures for the most recent year available (and retrospectively for a decade) of areas, population, employment and wages, production and consumption, transport and trade, for almost every country in the world. Countries were grouped alphabetically under their respective continents, with text in both English and French, and with very useful notes on sources, which could be followed up if greater detail were required.[1]

Since the beginning of 1947, the responsibility for the publication of international economic statistics has been assumed by the Statistical Office of the United Nations, which is under the Department of Economic Affairs. This agency collects information from the member nations and from the U.N. Special Agencies. The basic publication is the *Monthly Bulletin of Statistics*, which provides averages for each year from 1937, and monthly figures for two years previous to the date of issue. It is not confined to the member states of the U.N.O., but there are some obvious gaps. Users of the *Monthly Bulletin* should have the *Supplement: Definitions and Explanatory Terms*, which provides a vast amount of information concerning the statistics and their derivations, and gives useful leads to more detailed sources. This is especially essential when comparing figures for a number of countries, because the bases and formulae from which the published statistics are derived often differ appreciably from one country to another. In addition to the *Monthly Bulletin*, there appeared in 1949 the first *Statistical Year-Book* of the United Nations Organization, referring to 1948, and a second volume appeared in the following year. The latter contains 166 tables, providing in most cases retrospective annual figures from 1935 to 1949, which are as nearly comparable as the statistical surveys of member countries will permit. With a very full index and notes, it is an indispensable source-book for an economic geographer.

The U.N. Statistical Office publishes also a wide range of other economic summaries; these are too numerous to list here, but details can be obtained from the various U.N. agents. Many other international agencies, for the most part directly or indirectly associated with the U.N.O., publish statistical abstracts and year-books; these agencies include the International Institute of Agriculture and the International Labour Office.

Official Government Publications. Most countries publish statistics of

[1] Other League of Nations publications included *Raw Materials and Foodstuffs: Production by Countries, 1938* (Geneva, 1940); *International Trade in Certain Raw Materials and Foodstuffs* (Geneva, 1939); *World Economic Survey, 1938–9* (Geneva, 1939); *Review of World Trade* (annually); and *International Trade Statistics* (annually).

their national resources and economic activities, some in more detail than others. The *Supplement* produced by the U.N. Statistical Office has a most useful Bibliography which gives the main official statistical publications of sixty-six countries. Most of these countries have a single annual publication, which takes the form of some kind of Abstract or Year-Book.[1]

These national statistical year-books are extremely useful, as they provide for the economic geographer the detailed information of production and distribution of commodities on a regional administrative basis: by counties, *départements* and provinces. Most countries, too, produce statistical summaries at more frequent intervals than the year-books.[2] Finally, the statistical offices of many countries issue a range of more specialized publications.[3]

Other Published Statistical Information. A large amount of statistical material is issued by industrial concerns, both by individual firms and by cartels, such as the British Iron and Steel Federation and Unilever. Banks and commercial houses are also prolific sources.[4] Finally, mention must be made of the various periodicals devoted to economic surveys, which often provide most convenient and authoritative data.[5]

The statistical sources already mentioned may appear overwhelming, especially as they represent only a few examples. The economic geographer, however, selects only the material he requires for his particular work. If it be a general survey of the world output of some commodity, he requires only summary figures, and these can be obtained from some general international source. If it be a more detailed study of some aspect of the economic life of a particular country, he can begin with the relevant Year-Book, and as his work

[1] Three examples are the *Statistical Abstract*, published by the United Kingdom Central Statistical Office; the *Annuaire Statistique de la France*, published by the Institut Nationale de la Statistique et des Etudes Economiques for the Ministère de l'Economie Nationale; and the *Jaarcijfers voor Nederland*, published by the Centraal Bureau voor Statistiek at The Hague.

[2] The *Economic and Statistical Bulletin of Southern Rhodesia*, for example, appears fortnightly, and almost every country has a monthly Bulletin.

[3] The output of statistical information in the United Kingdom, for example, is so vast that the student can only be referred to the *Consolidated List* and the *Sectional Lists*, such as those produced for the Ministry of Agriculture and the Ministry of Fuel and Power; these lists are issued at intervals by H.M. Stationery Office. Similarly, the Institut National de la Statistique of France has issued no less than 120 *Etudes Speciales*.

[4] For example, the *Rotterdamsche Bankvereeniging Quarterly Review* contains authoritative data concerning many aspects of the economic life of the Netherlands. Industrial directories, such as the *Indicateur des Produits Belges*, published by the *Fédération Nationale de Chambres de Commerce et d'Industrie de Belgique*, are indispensable for a study of the industry of any country.

[5] See, for example, the numerous Industrial Supplements of *The Times* and the *Manchester Guardian*, and the *Bulletin de l'Institut de Recherches Economiques*, published at Leuven.

develops he will have to consult more detailed and necessarily more specialized sources.

Unpublished Statistical Information. For most research work it is often essential to obtain access to unpublished statistical material. Thus to construct the agricultural maps of north-eastern Belgium (Figs. 106–9) on a commune basis, it was necessary to consult many hundreds of manuscript returns in the archives of the Institut National de Statistique in Brussels, and to draw the diagram of freight-movement along the Juliana Canal (Fig. 122), the unpublished figures were supplied by the Centraal Bureau voor de Statistiek at The Hague. A study of the Kempen coalfield and the construction of a series of maps to illustrate the production and export of coal from that field entailed visits to each of the seven collieries and to the coal-port at Genk on the Albert Canal. The gradual tracking-down of this information as the work proceeds is indeed one of the fascinations of an enquiry into some aspect of economic geography.

Agricultural Statistics

Statistics of agricultural areas, yields and values are compiled, tabulated and published by the Ministry of Agriculture, or the equivalent government department, for most countries. The raw material of these summaries consists of the collated census forms, completed by each farmer in every parish, commune or similar administrative unit.

For England and Wales and for Scotland, summaries are published on a county basis of the area of arable land, grassland, land under each of the major crops, the yield per acre of each of these, the numbers and categories of animals, and details about farm-labour. The total areas of each county are also tabulated, so that densities can be calculated. If more detailed figures than on a county basis are required, it is necessary to extract the information for each parish from the files of the Ministry of Agriculture, but details for each individual farm are confidential.

Belgium may be quoted as a second example. Agricultural censuses have been held there at intervals since 1846; the results of each of these censuses were published in several large volumes in immense detail on a commune basis, and are invaluable source-books. To replace these large-scale publications, which have become increasingly expensive to produce, an annual summary has been brought out since 1939; up to 1945 information was presented on a basis of *cantons*, but since then the increasing need of economy has limited the publication to a basis of *arrondissements* only. The unpublished details for the individual communes for each year are available in the files of the Institut National de Statistique in Brussels.

Industrial Statistics

The range of industrial statistics includes the production and consumption of fuel and power and of raw materials, and the output of semi-finished and finished manufactures. Returns vary enormously, and if comparisons are being made between different countries, care must be taken to examine the bases of the figures used. This problem may be illustrated by the consideration of one useful comparative figure, the index of industrial production. An overall index is calculated for each country, which can be used to measure changes in the physical volume of industrial output, and is converted to relate to the base of 100 for the year 1937. The index numbers are computed according to the weighted aggregate method; the basic data used are the actual quantities produced by a select series of industries, while the weighting may consist of the gross value of production, or of the number of workers, or of man-hours.[1]

In some countries, notably in Great Britain, useful indications of industrial activity are provided by the numbers of people employed in a particular industry.[2] Thus the numbers of operatives in various Lancashire textile mills, or the number of men employed in the collieries of a particular coal-field, can be used as a basis for a detailed distribution map of the textile industry or of the coal-field (Fig. 110). The problems involved in handling these occupational statistics are discussed on pp. 222-4.

Transport and Communication Statistics

Trade statistics, i.e. figures of imports and exports, which reflect so much of the economic life of a country, are available for most countries on a commodity basis in terms of both weight and value, and of the origin and destination of the commodities concerned. Various countries use different classifications and groupings of items, and values are subject to very intricate definitions because of Customs requirements.

An analysis of the activity of a port, which is a most interesting aspect of economic geography, must necessarily include a close study of its external trade.[3] In addition, the entrances and clearances of national and foreign sea-going shipping in terms of net registered tonnage, and of passenger traffic for the 'ferry ports', are required. It is essential to

[1] See, for example, the *Monthly Bulletin of Statistics, Supplement: Definitions and Explanatory Notes* (Statistical Office of the United Nations, New York, 1948); on pp. 22–48 a comparison is made between the industrial returns of various countries, and the differences are emphasized.

[2] See, for example, *List of Mines, 1948* (H.M.S.O., 1949).

[3] See, for example, *Annual Statement of the Trade of the United Kingdom* (London, annually).

examine the criteria upon which the statistics of the ports of the particular country are based; thus French returns include deep-sea fishing vessels; some countries include vessels in ballast, while others exclude them; some omit vessels below a certain minimum size; and so on.

The statistics available for a study of rail, road and water transport vary enormously. Rail figures, including track- and route-length, numbers of locomotives and rolling-stock, and freight and passengers conveyed, are as a rule available for operating regions or districts, as in France and Germany; in France, the returns are published for the four regions of the Société Nationale des Chemins de Fer Français, in Germany before 1939 returns were available in somewhat more detail for the forty-one traffic districts. But for a country like Belgium only total figures for the whole country can be obtained, which makes the analysis of freight-movement a difficult or even impossible task.

Few statistics are published relating to road-transport. Occasionally traffic-censuses are taken; thus in Belgium three such censuses have been held, in 1908, 1926 and 1933, when continuous observation was maintained at a thousand points for twenty-four hours. Other sources of information, such as the analysis of motor-bus time-tables, are sometimes helpful (see pp. 285, 316).

The statistics referring to individual inland waterways are usually published in considerable detail, especially for west European countries, since the numbers of vessels and the volume of freight can be easily recorded at the locks; thus it is possible to find the total freight conveyed and the major freight categories, either in terms of tons absolute or of ton-kilometres. The latter figure is derived from the product of each load in tons and the actual distance it travels. It is therefore applicable to the whole length of the waterway, unlike figures of absolute tonnage, which are usually measured at a particular lock, and so may include both short and long-distance loads. The figure of ton-kilometres makes adjustments between the different distances travelled, and so gives a reasonable impression of 'work done'. To compare activity between one waterway and another, an index of ton-kilometres per kilometre of length can be calculated, which represents a value adjusted in proportion to the actual length of the route. Thus a long waterway would have a large return of ton-kilometres because of its length, but might be no more busy than a short waterway. Ton-kilometres per kilometre, therefore, produces a strictly comparable impression of the relative importance of each waterway.[1] Figures can

[1] For a full discussion of this problem, with particular examples of the maps which can be drawn from the various statistics available, see F. J. Monkhouse, 'Coal Movement in Belgium, with Special Reference to the Kempen Field', *Publication No. 17, Transactions and Papers, 1950: The Institute of British Geographers* (London, 1952).

often be obtained of actual loadings and unloadings at ports along each waterway in tons absolute.

Non-Quantitative Maps

The Chorochromatic Technique. The most obvious type of economic map is that which shows areal distributions without any quantitative

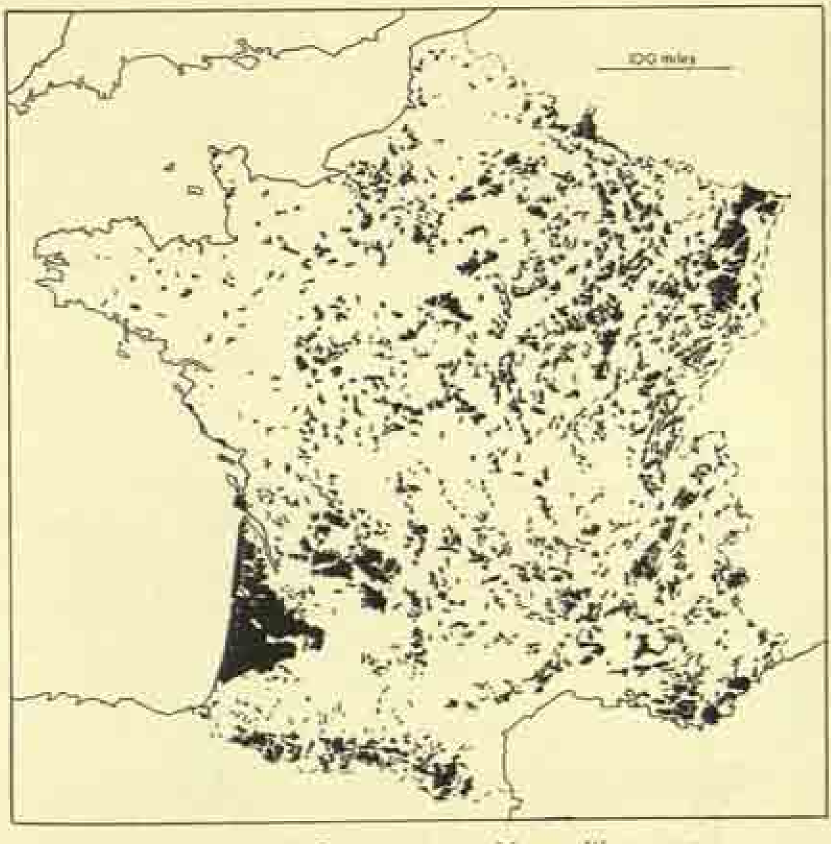
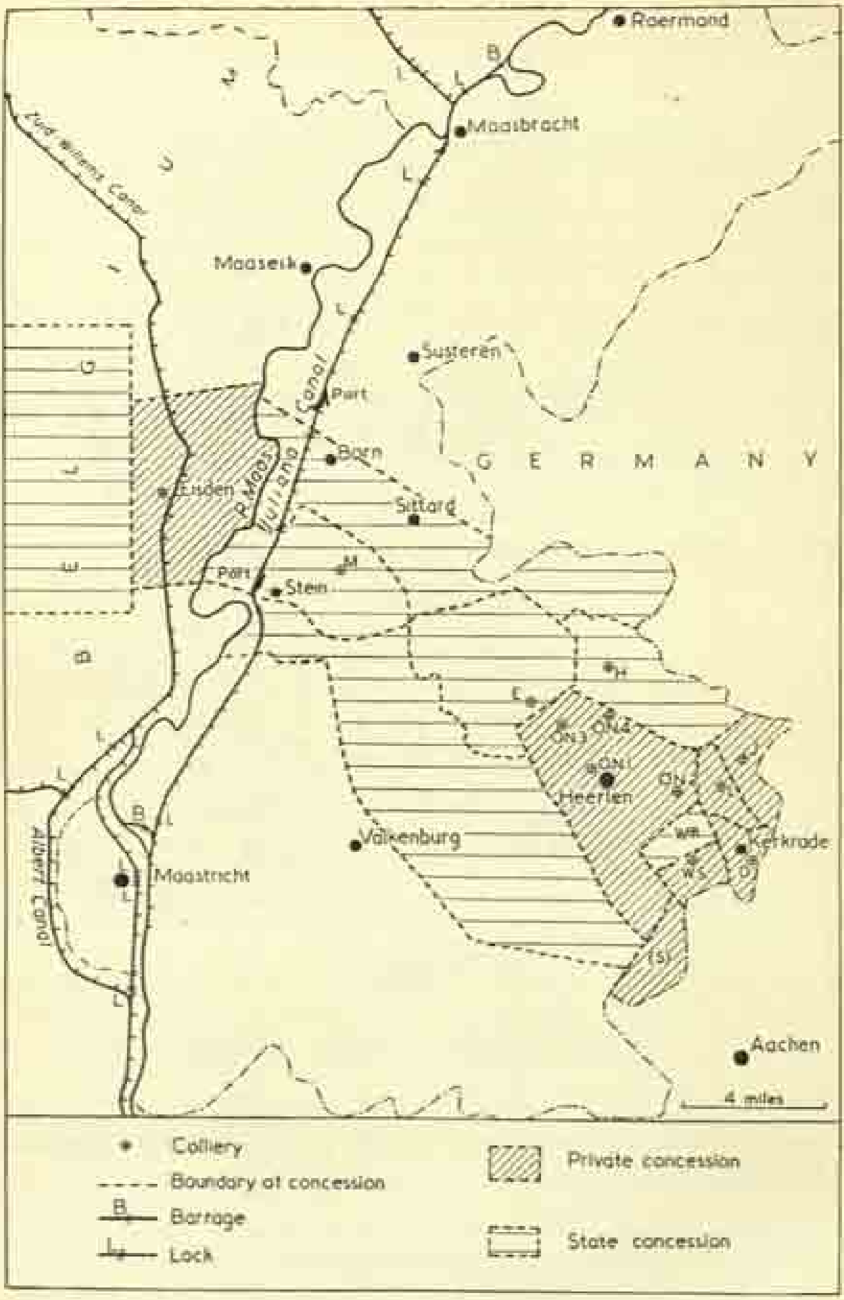


Fig. 92. A Chorochromatic Map of Woodlands

Based on the *Atlas de France*, plate 38 (Paris, 1935).
This map refers to 1931. The significance of the Landes and the upland areas (note especially the indication of the escarpments bounding the eastern Paris Basin) is brought out clearly.

indications. These areal distributions may be either *simple*, merely showing the extent of a single element for definition purposes, or *compound*, differentiating between a series of associated elements on the



Roermond
B
L
Maasbracht
Zuid Willems Canal
Maaseik
Susteren
Port
Born
G E R M A N Y
Elsden
R. Maas
Juliana Canal
Sittard
M
Port
Stein
H
E
ON3
ON4
ON1
ON2
Heerlen
WR
Kerkrade
WS
D
Valkenburg
Maastricht
Albert Canal
(S)
Aachen
4 miles
Colliery
Boundary of concession
Barrage
Lock
Private concession
State concession

same map. Basically, this method implies the drawing of bounding lines to delimit specific areas, within which is applied some distinctive shading or colouring. These areal distribution maps can be drawn on any scale, showing a single farm, or a parish, a county, a country or even a continent; obviously the smaller the scale, the more generalized and the less accurate must the map become, as small-scale maps in economic atlases frequently show.

Land-utilization maps are probably the best-known and most commonly used of this type of agricultural map. The detail is surveyed on the ground and plotted on a large-scale outline, field by field, to distinguish between arable land, temporary or permanent pasture, orchards and so on, or even in more detail to show the arable land under various crops. Such a map can be drawn on a six-inch scale and then reduced photographically to a one-inch or smaller scale. Moreover, material can be extracted from a general land-use survey to portray particular elements, such as the extent of woodland (Fig. 92), or of heathland, or of irrigated lands.[1] At the other end of the scale of generalization is the broad distribution map, such as one showing the extent of the American wheat, corn and cotton belts, which is of value only in an elementary text-book.

Industrial maps can also be constructed on the same principle. These will include maps of coal-fields, ore-fields and oil-fields, the limits of which can be extracted either from a geological map (Fig. 111) or from a plan of the concessions (Fig. 93), and of maps of land devoted to industrial uses, which can be plotted in the field. Point symbols (see below) can be inserted over the chorochromatic shading to locate the actual collieries, oil-wells and so on, as is done on Fig. 93, thus producing what may be called a *choroschematic* map.

The outline of the distribution area is drawn in, and then shading or colour-tinting is applied. Solid black is preferable for widely scattered small areas of a single element (Fig. 92), particularly if any

[1] L. D. Stamp, *The Land of Britain, its Use and Misuse* (London, 1948), presents many examples of extraction and reduction from large-scale field surveys.

Fig. 93. A Choroschematic Map of the South Limburg Coalfield

Based on P. R. Bos and J. P. Miermeyer, *Schoolatlas der Geheel Aarde*, plate 11B (Groningen, 1936).

The following letters are used to indicate the names of individual collieries: **D.** Domaniale; **E.** Emma; **H.** Hendrik; **J.** Julia; **L.** Laura; **M.** Maurits; **O.N. 1, 2, 3, 4.** Oranje Nassau 1, 2, 3, 4 collieries; **W.** Wilhelmina; **W.S.** Willem and Sophia.

Both shading (to indicate private and State concessions) and point symbols (to indicate collieries, barrages and locks) are utilized.

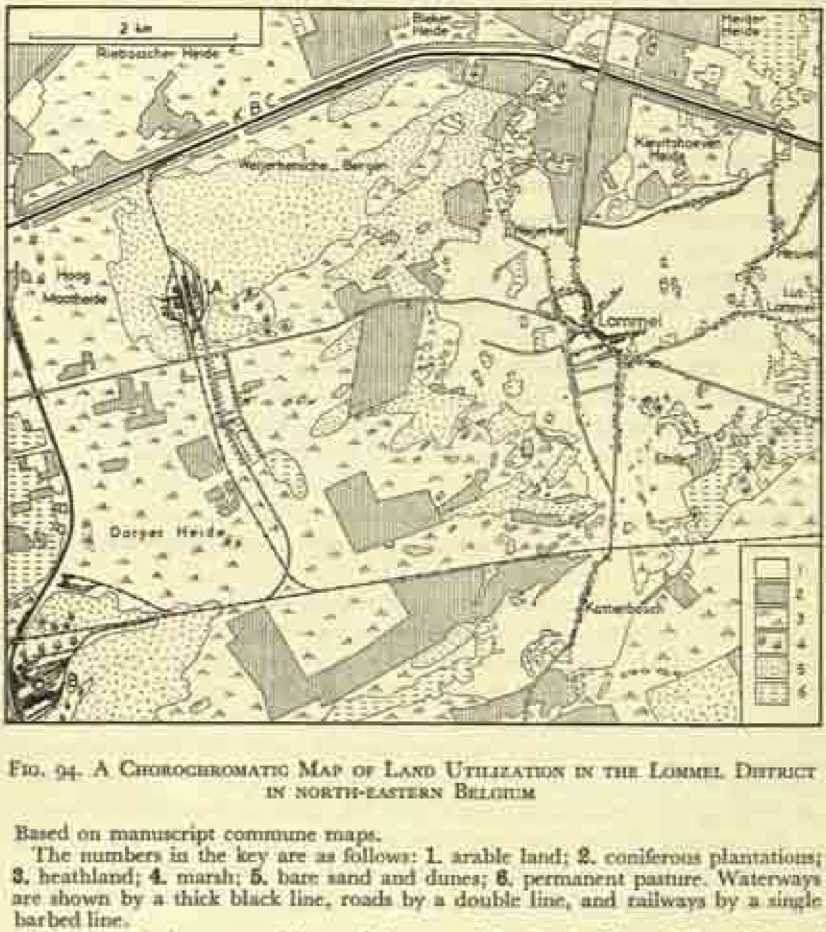


Fig. 94. A Chorochromatic Map of Land Utilization in the Lommel District in north-eastern Belgium

Based on manuscript commune maps.

The numbers in the key are as follows: **1.** arable land; **2.** coniferous plantations; **3.** heathland; **4.** marsh; **5.** bare sand and dunes; **6.** permanent pasture. Waterways are shown by a thick black line, roads by a double line, and railways by a single barbed line.

The abbreviations are as follows: **A.** factory of the *Cie des Métaux d'Overpelt-Lommel et Corphalie*; **B.** factory of the *S.A. des Mines et Fonderies de Zinc de la Vieille-Montagne*; **B.B.C.** *Beverloo Branch Canal*; **K.B.C.** *Kwaadmechelen-Bocholt Canal.*

Lommel is situated near the Netherlands frontier in north-eastern Belgium. The main part of the village has grown up at the point of convergence of five roads and along their inter-connections, and has spread along these roads towards a ring of small hamlets lying a mile or two from the centre of the village. Surrounding the group of houses is a series of almost concentric zones of different land utilization. First there is an area of predominantly arable land, only about a mile in width to the west but nearly five times as wide to the east. There are small scattered patches of permanent pasture, and more continuous tracts in the valleys of the numerous small streams. On the edge of the cultivated land lies an incomplete belt of woodland, one to two miles from the commune centre. Beyond this is the heathland, which in parts is exceptionally bare and desolate. To complete this picture of a typical Kempen commune, in the extreme west there are large zinc and chemical works, each with its housing-estate.

reduction is intended, but if several forms of land-use appear on the same map distinctive shading or tinting must be used (Fig. 94).

Delimitation of Hinterlands

A category of areal map of special interest to the economic geographer is that which seeks to delimit an area of influence such as a port hitherland, and this obviously involves a problem of some complexity. A pattern-map can show railways and waterways converging upon a port, a columnar diagram can depict the shipping and freight handled by the port, while a map can be drawn on which appear concentric circles to represent specific distances from port centres; the last is useful when transport charges on a distance basis form a high proportion in the selling costs of goods.[1]

F. W. Morgan produced a series of maps to depict the pre-1939 hinterlands of the major German ports.[2] He was able to draw these maps because of the detailed nature of the German statistics. Thus railway despatches and loadings were returned for forty-one traffic-districts within Germany and for twenty-six outside, and returns of traffic were available for each waterway. By studying the freight-flow by rail and water to and from the major ports, Morgan was able to delineate 'commodity hinterlands'. On his maps he indicated the hinterland of each port by a line bounding traffic-districts which despatched to and received from the respective port at least 50,000 tons of freight; this figure was of course an arbitrary one, but it was chosen as being of a significant and representative order of magnitude. As a rule, statistics are not available for such a detailed depiction of hinterlands.

Linear Patterns

The networks of road, railway and waterway systems can be extracted by tracing from detailed topographical maps. The only problem is the classification of specific categories, which may be indicated by different types of line (Fig. 2) or thicknesses of line. Thus on a railway map, it may be necessary to distinguish single, double, multiple and electrified lines, or to differentiate between main-line and light railways, between broad, standard and narrow-gauge tracks.

[1] A. C. O'Dell, 'Port Facilities and the Dispersal of Industry: the Problem in Scotland', *Geographical Journal*, vol. 97 (London, 1941), shows on p. 115 the relation of ports to the industrial areas of the Midland Valley of Scotland by drawing distinctive circles at distances representing both 25 miles and 10 miles from a major port, and 10 miles only from a minor port.

[2] F. W. Morgan, 'The Pre-War Hinterlands of the German North Sea Ports', *Transactions and Papers, 1948: The Institute of British Geographers* no. 14 (London, 1949); and 'The Pre-War Hinterlands of the German Baltic Ports', *Geography*, vol. 34 (London, 1949).


O Miles 30
NOVI SAD


O Miles 30
KOSOVSKA
MITROVICA


O Miles 30
ZAGREB

Waterways are usually classified on the basis of the size of vessel accommodated, while road maps should show the various widths, grades of surface, and official classifications. Compare, for example, the road patterns in three parts of Jugoslavia (Figs. 95–7). The visual impression of main and local road density derived from these patterns is a striking reflection of the diverse geographical features of these three parts of the country. In addition to these 'system maps', detailed plans can also be drawn of sidings and marshalling-yards, city 'lay-outs', sea-ports and canal-ports.

The patterns of such route-ways as ocean highways and airways can be drawn by linking scheduled points en route. Care must be

FIG. 98. A NON-QUANTITATIVE SYMBOL MAP OF THE BELGIAN TEXTILE INDUSTRY

Based on various industrial directories, including *Indicateur des Products Belges* (Bruxelles); *Comité central industriel de Belgique: Liste des Etablissements industriels affiliés* (Bruxelles); and *Official Directory of Belgian Exporting Manufacturers* (Brussels).

The map shows the general distribution of the various branches of the industry, particularly its concentration in Flanders, with the outlying woollen centre of Verviers.

FIGS. 95–7. ROAD-PATTERN MAPS OF JUGOSLAVIA

Based on *Automobiliska Karta*, 1:1,000,000, published by the *Jugoslovenska Standard-Vacuum-Oil Company* (Beograd, n.d.). The map refers to the pre-war situation.

The main roads are shown by heavy lines, main roads under construction by heavy pecked lines, and minor roads by fine lines. The frontier is indicated by a dotted line.

The maps are of (top) areas in the Vojvodina, (middle) the Region of Kosmet, and (bottom) Croatia. The main roads are evenly distributed over the whole country, the minor roads are an indication of density of population and of prosperity.

taken on the small-scale maps with the projection. The actual route on many projections is not the shortest line between two points, as frequently happens on many small-scale maps in elementary text-books. Frequently, however, such route-maps are made in a generalized and diagrammatic form.

Symbols

Non-quantitative distributions centred at a point may be shown

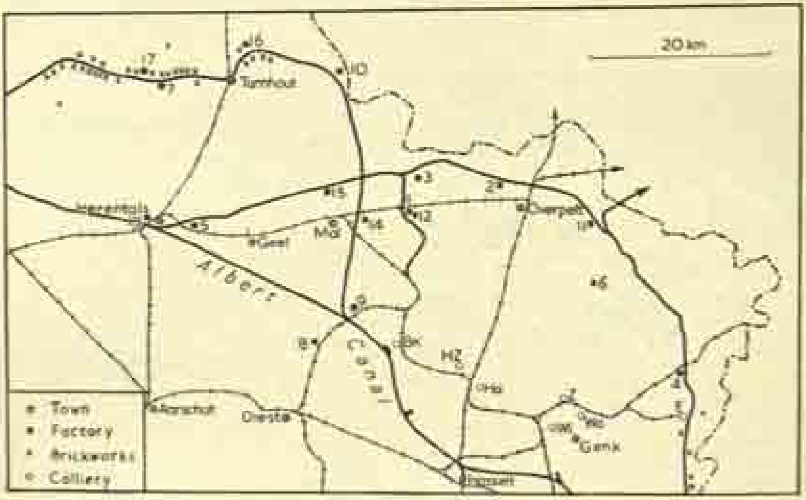


FIG. 99. THE USE OF SYMBOLS IN INDUSTRIAL LOCATION

Based on F. J. Monkhouse, *The Belgian Kempenland*, p. 147 (Liverpool, 1949).

For ease of reference, the factories have been numbered, and the seven collieries indicated by their initial letters. Main line railways are shown by barbed lines, navigable waterways by solid lines.

quite clearly by symbols, whether geometrical, pictorial or litteral (i.e. shown by an initial letter). Thus Fig. 98 gives some indication of the distribution of the various branches of the Belgian textile industry; a black disc was placed over each wool-manufacturing centre, a black triangle over a cotton centre, and so on. Its advantage is limited in that there is no indication of relative importance; thus the square at Gent, the centre of the industry, is the same size as the one at Tielt or Ronse. But it does show the concentration in the Lys and Scheldt valleys, with the outstanding exception of the group of woollen towns near Verviers. Fig. 99 shows on a larger scale the precise location,

with specific reference to railways and waterways, of the seventeen major factories and the seven collieries in north-eastern Belgium; such a location map is indispensable for an analysis of the development of the Kempenland in the twentieth century as a new major industrial region. If the symbols are drawn proportionally to scale, a quantitative element is introduced; these media are discussed below.

Isopleth Maps

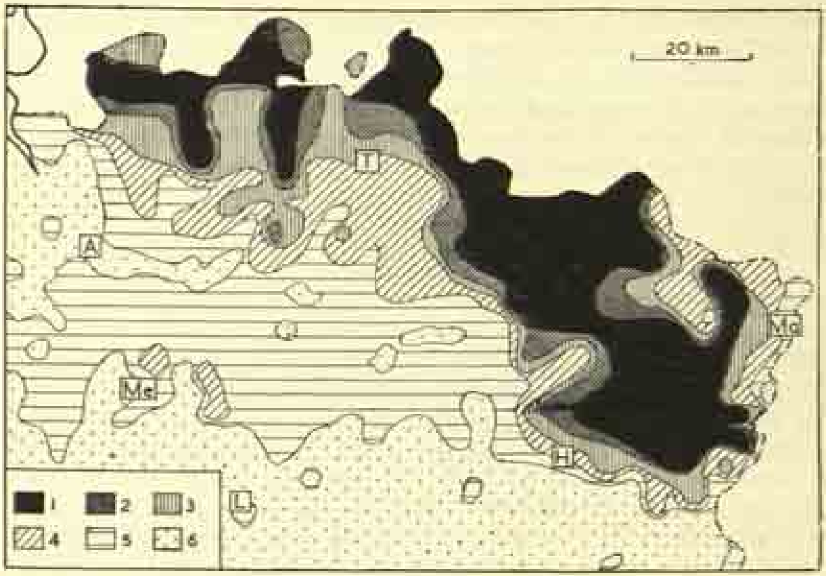
Agricultural Isopleths

If sufficiently detailed data are available, isopleths can be used with effect to express ratios between associated agricultural phenomena. Frequently, in fact, these quantitative ratios are much more revealing and significant than the absolute values of the related elements as portrayed separately. The simplest application is when the ratio is between the total area of a unit and that area under some specific land-use, such as crop-acreage ratios, or the proportion under permanent pasture. Fig. 100 shows an isopleth map of the distribution of heathland in north-eastern Belgium in 1866; it is useful to compare this with Fig. 101, which is a choropleth map constructed from the same data. Other ratios include the number of animals per square mile, or of livestock units per square mile, or of such interesting correlations as the yield per unit and the rainfall total during the growing season, the amount of milk produced compared with the area under all crops expressed in gallons per annum per acre,[1] and many more. In addition, climatic isopleths, such as isotherms, isohyets, lines showing the length of the growing season or the duration of freedom from killing frosts (Fig. 59), may be superimposed with very great effect upon a choropleth or dot map of agricultural distributions.

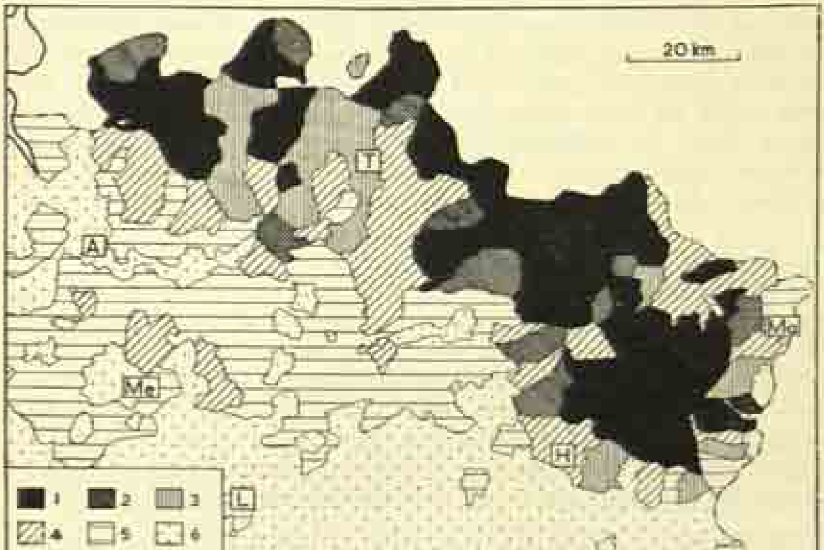
The Drawing of Agricultural Isopleth Maps. The method of drawing these isopleths depends upon the nature of the statistics available and the size of the units involved. Where the simple interpolation of isopleths is desired, figures must be available for sufficiently small units to allow a number of control points (see p. 30) to be plotted at the centre of each unit, as in the case of Fig. 100, for which proportional values were calculated for 666 communes. Similarly, W. D. Jones[2] placed his plotted points in the geometrical centre of each township.

[1] W. D. Jones, 'An Isopleth Map of Land under Crops in India', *Geographical Review*, vol. 19 (New York, 1929); and 'Ratios and Isopleth Maps in Regional Investigation of Agricultural Land Occupance', *Annals of the Association of American Geographers*, vol. 20 (Lancaster, Pa., 1930). The very interesting map of milk-crop ratio appears in the second reference, on p. 193.

[2] W. D. Jones, *op. cit.*



20 km
T
A
Mg
Me
H
L
1
2
3
4
5
6



20 km
T
A
Mg
Me
H
L
1
2
3
4
5
6

R. R. Rawson, on the other hand, dealing with mainly square administrative units in the Dakotas, shaded those squares representing counties with more than 15 per cent of the total farm-land under wheat, and then somewhat arbitrarily smoothed off the square boundaries to form isopleths.[1] A third technique was used by E. R. Payne, who first constructed a series of dot-maps, to show beef-cattle, dairy-cattle, and actual areas of arable land, and superimposed over each map a grid, each square of which represented 4 square miles on the ground.[2] She counted the number of dots falling in each square, next delimited those particular squares containing certain critical quantities, and finally smoothed out the square boundaries and replaced them with generalized isopleths.

'Accessibility' Isopleths

Isopleths can be used to supplement linear-pattern maps of transport systems. One type of 'distance map' can be constructed where isopleths represent values calculated in terms of miles of road per hundred square miles of area. From an inspection of a road-pattern map, the country is divided into areas within each of which the density of the road network is broadly uniform, and that density is calculated in terms of miles per 100 square miles, by measuring the length of road within each area with an opisometer and finding the area with a planimeter. The values at the centre of each area are plotted, and isopleths interpolated at various intervals.

As an alternative method, the route-map may be gridded, the length of route measured in each square, and an average figure obtained, which is then placed in the centre of the square. Each of these methods bring out the areas of high, average and low density,

[1] R. R. Rawson, 'The Agricultural Geography of the Dakotas', *Geography*, vol. 25 (London, 1940).

[2] E. R. Payne, 'The Agricultural Regions of the Market Harborough-Rugby Area', *Geography*, vol. 31 (London, 1946).

FIGS. 100, 101. ISOPLETH AND CHOROPLETH MAPS OF BELGIAN HEATHLANDS, 1866

The data of heathland in each commune were obtained from *Agriculture: Recensement Général* (Bruxelles, 1866). The boundaries of the communes were taken from the *Carte de Belgique—1:320,000, Comportant la Subdivision Administrative du Territoire* (Bruxelles, 1938). The area of each commune (from which the densities were calculated) was taken from the *Recensement Général de la Population 1866* (Bruxelles, 1870).

The figures in the key indicate the percentage of the total area of each commune under heath as follows: **1.** over 40; **2.** 30 to 40; **3.** 20 to 30; **4.** 10 to 20; **5.** 1 to 10; **6.** under 1.

The towns are indicated by abbreviations, as follows: **A.** Antwerp; **H.** Hasselt; **L.** Leuven; **Ma.** Maaseik; **Me.** Mechelen; **T.** Turnhout.

and so helps to correct the impression of even density which a pattern-map might otherwise convey.

Another type of 'distance-isopleth' map was constructed by L. D. Stamp, who drew lines to indicate areas more than five miles from a railway and the same distance from an 'A' road respectively.[1] The areas thus defined were filled in black for emphasis.

A group of 'accessibility isopleth' maps involve both time and distance; these are often known as 'travel-speed' maps. E. G. R. Taylor used generalized isopleths (to which is given the name of *isochrone*) to divide England and Wales into four zones in respect of accessibility by rail to and from London, Leeds, Liverpool, Newcastle, Manchester and Birmingham.[2] A different application of this idea was used to show the travel time in days from Boston in the years 1790–98,[3] while yet another depicted New York as a centre of travel in 1800, 1830, 1857 and 1930, stressing the progressive acceleration in travel.[4] S. W. Boggs elaborated this principle by drawing a series of *isotachic maps*, to illustrate the distances that may be feasibly travelled by surface means in 1940, in all directions.[5] He delimited distances of 50 to 100, 100 to 250, and 250 to 500 miles per day in terms of available roads, and also added a category of over 1,000 miles by rail. He assumed that travelling was carried out by the fastest possible means, whether by horse, automobile or railway, but excluded aircraft, and he used the positions of the roads and railways as "ribbons of land dedicated to movement" to help to define his areas. Four grades of shading were added between the isotachs.

Isopleths and Economic Regions

The linear quality of isopleths lends itself readily to the delimitation of a region, whether it be climatic, agricultural, or industrial. Isopleths can be superimposed to give a quantitative impression of all the factors bearing upon the definition of a particular region.

Agricultural Regions. As Hartshorne and Dicken wrote in 1935, "the great advance which Köppen made in the study of climatic regions by the use of the statistical method can also be expected in the similar study of agricultural regions based on statistical criteria, thereby put-

[1] L. D. Stamp, *op. cit.*, p. 209.

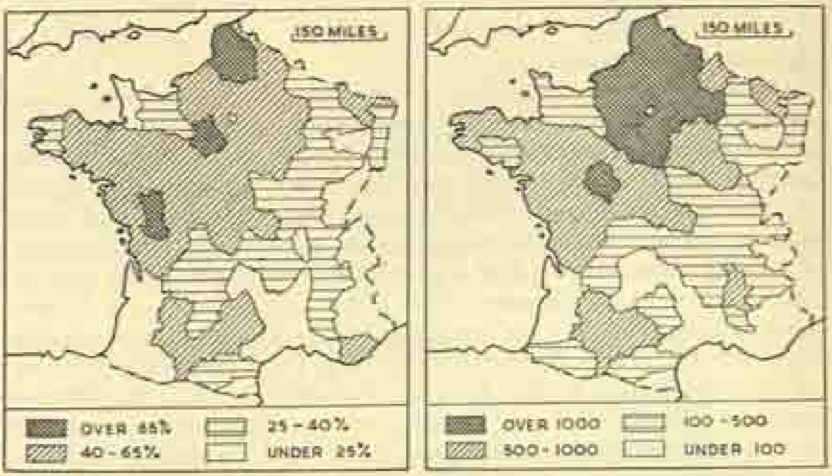
[2] E. G. R. Taylor *et al.*, 'Discussion on the Geographical Distribution of Industry', *Geographical Journal*, vol. 92 (London, 1938).

[3] E. Staley, *World Economy in Transition* (New York, 1939).

[4] Edited J. K. Wright, *Atlas of the Historical Geography of the United States* (New York, 1932).

[5] S. W. Boggs, 'Mapping the Changing World: Suggested Developments in Maps', *Annals of the Association of American Geographers*, vol. 31 (Lancaster, Pa., 1941).

ting on a scientific basis a significant aspect of the study of the cultural landscape".[1] These geographers drew a series of maps of Europe and the United States on which appeared a variety of isopleths based on crop-acreage ratios, and then they chose the most significant of these isopleths to delimit their regional types of agriculture.



FIGS. 102, 103. CHOROPLETH MAPS OF FRENCH AGRICULTURAL DISTRIBUTIONS

The data were taken from *Statistique Agricole Annuelle* (Paris, 1938).

Fig. 102 represents the percentage of arable land in each *département*, 1938. Fig. 103 represents the production of wheat in quintals per 100 hectares of each *département*, 1938.

Two further examples of this method deserve mention. Rawson[2] constructed isopleth maps based on quantities established for each county in the two states of North and South Dakota, and a superimposition of various isopleths enabled the agricultural divisions to be delimited. E. R. Payne[3] superimposed isopleths upon maps of the Market Harborough-Rugby area, and so delimited agricultural regions by assessing the overlap. Thus one of her regions was defined as having over 850 beef cattle, less than 400 acres of arable land, and less than 375 dairy cattle per unit of four square miles.

Industrial Regions. E. G. R. Taylor produced a map upon which all areas in Great Britain unsuitable for industrial location were indicated

[1] R. Hartshorne and S. N. Dicken, 'A Classification of the Agricultural Regions of Europe and North America on a Uniform Statistical Basis', *Annals of the Association of American Geographers*, vol. 25 (Lancaster, Pa., 1935).

[2] R. R. Rawson, *op. cit.* [3] E. R. Payne, *op. cit.*

in solid black.[1] These areas were determined by superimposing isopleths representing certain specific factors, such as contours, density of population isopleths, distance isopleths from nodal cities, and so on. This process was termed 'sieving-out' and the resultant maps are sometimes referred to as '*sieve-maps*'.

Choropleth Maps

Agricultural Choropleths

Choropleth maps of economic distributions are of very wide usage. Many statistics, particularly of agricultural returns, are published on a basis of administrative divisions. Figures of areas, total yields, average yield per unit of area, total values and the like are presented in tabular form in agricultural censuses. From these, various ratios and proportions for each administrative division can be calculated, a scale of values chosen, and a graduated system of shading applied. Such maps include the percentage of the total area of each division under arable (Fig. 102), the average size of holding in each, the average yield per unit of area for each division (Fig. 103), the average number of animals per unit of area for each division (Fig. 104), the value of farmland per unit of area, which gives a comparable impression of agricultural prosperity, and many more.[2] An interesting variation on a map showing the number of animals per unit of area is the *stock-index* map, on which the average number of 'stock units' per unit of area for each administrative division are indicated.[3] Similar ratio maps may be used to depict changes in land-use areas or yields over a period of time, as in Figs. 105–8, which show on a comparable basis the striking alteration in the proportions of arable land, permanent pasture, heathland and woodland in north-eastern Belgium between 1866 and 1946. The total area of each of 666 communes, together with the areas of the various land-use categories, were tabulated for

[1] E. G. R. Taylor, *op. cit.*

[2] G. T. Trewartha, 'Ratio Maps of China's Farms and Crops', *Geographical Review*, vol. 28 (New York, 1938), uses fifteen ratio maps, including the relation of cultivated to the total area, crop acreage per farm household, total crop acreage in relation to the cultivated area, the irrigated to the total area, and the proportion of the total area under various crops.

[3] W. Smith, *An Economic Geography of Great Britain*, p. 249 (London, 1948), has a map of north Northumberland, compiled by J. C. Dunn, in which stock units of cattle and sheep per 100 acres of the total area of each parish are computed, and a choropleth grading devised. Stock-units are here defined in a special index in relation to the specific conditions of the area as follows: cows and heifers in milk, cows in calf, 1; heifers in calf, ¾; other cattle, over 2 years, ¾; other cattle, 1–2 years, ½; calves, ¼; lowland ewes with lambs, ⅕; lowland yearling sheep, ⅙; hill ewes with lambs, ⅐; hill hogs and others, ⅛. The U.S. Department of Agriculture uses a different basis: 1 unit equals 1 horse, 1 mule, 1 cow, 7 sheep, 7 goats, and 5 pigs.

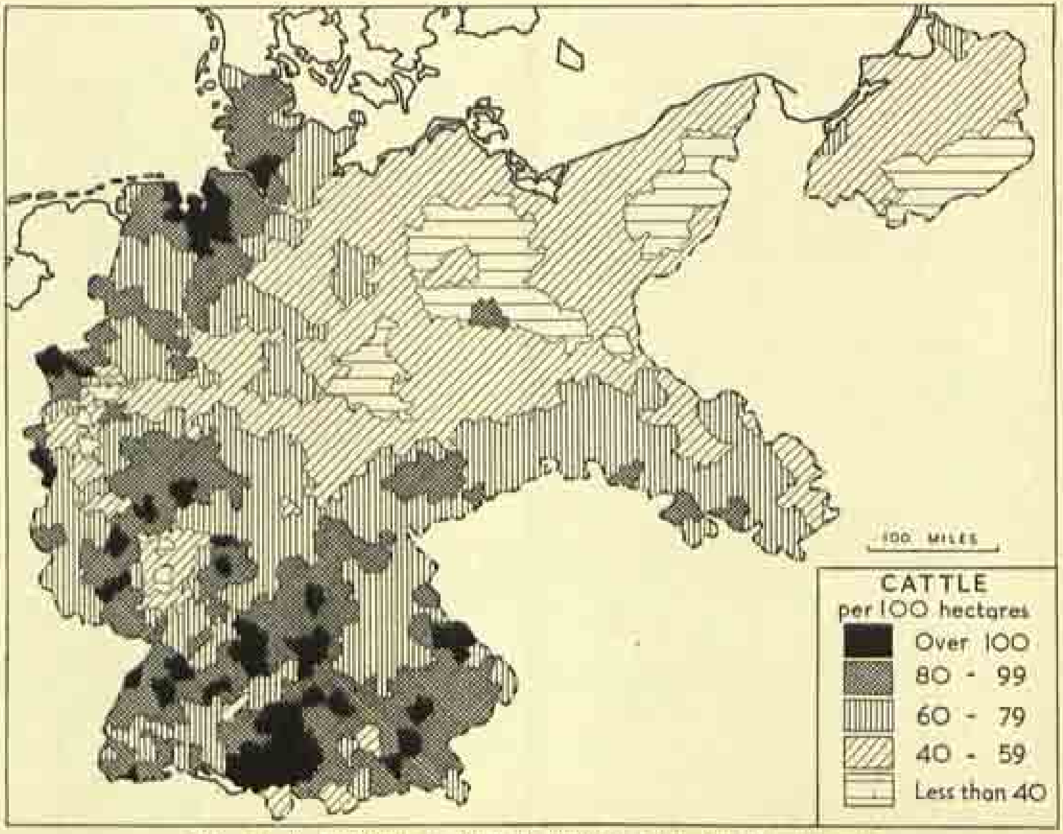
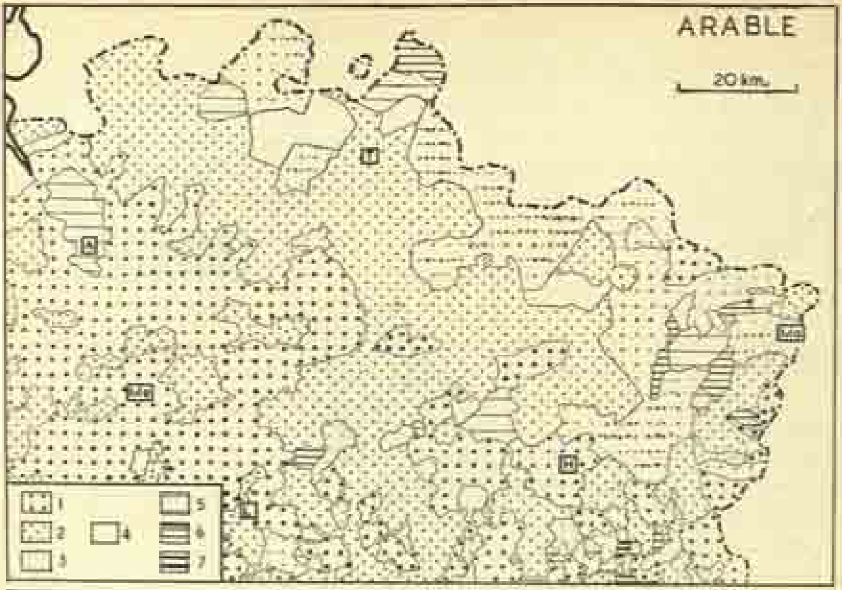
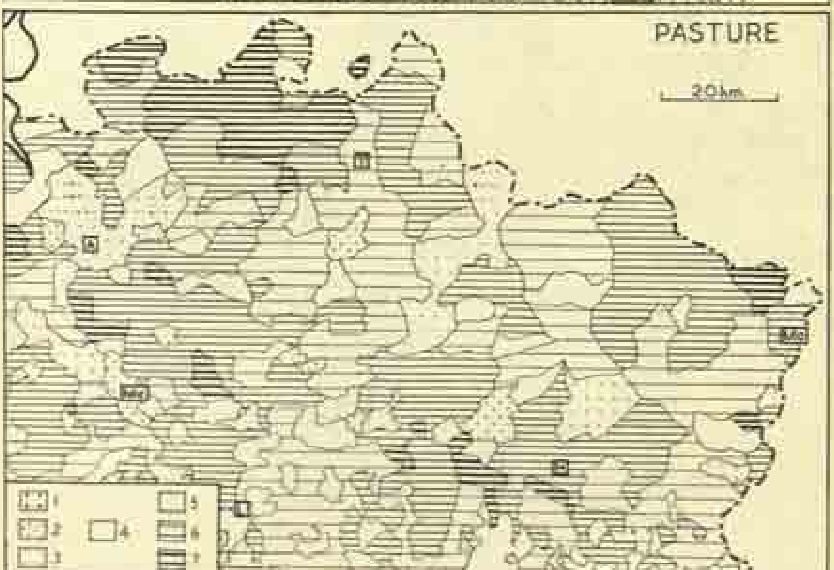


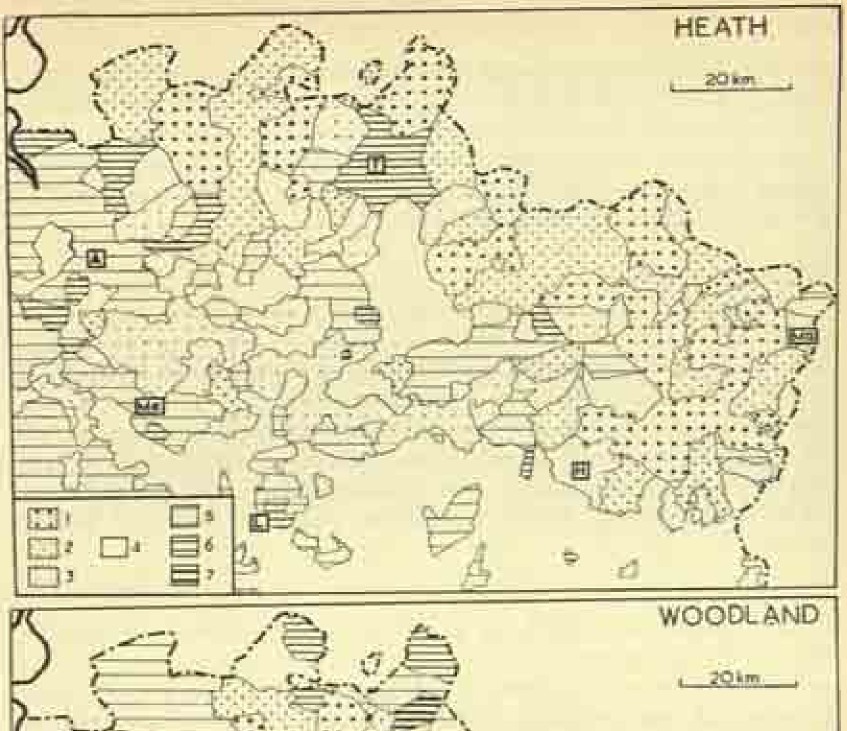
FIG. 104. A CHOROPLETH MAP OF GERMAN LIVESTOCK DISTRIBUTION
Based on the *Deutscher Landwirtschaftsatlas*, map 55 (Berlin, 1934).





FIGS. 105–8. CHOROPLETH MAPS OF LAND-

The change in each commune, for each of the four categories, was calculated from data obtained from *Agriculture: Recensement Général* (Bruxelles, 1866), and from results of the unpublished cadastral survey of 1942, made available by the *Institut National de Statistique* in Brussels.



UTILIZATION CHANGES IN THE KEMPENLAND, 1866–1942

The figures in the keys indicate the change in the areas of the four categories, between the two surveys, expressed as a percentage of the total area of each commune, as follows: **1.** decrease exceeding 25; **2.** decrease of 10 to 25; **3.** decrease of 2 to 10; **4.** little or no change, i.e., less than plus or minus two; **5.** increase of 2 to 10; **6.** increase of 10 to 25; **7.** increase exceeding 25.

the two dates, and the change over the period was expressed as a percentage of the total area for each commune. Particular care had to be taken in cases where the area of a commune had changed, or where communes had been created or had been merged with others; separate values had to be calculated for those pieces of land not comparable for the two dates as whole communes.

Industrial Choropleths

Choropleth maps are infrequently used for industrial maps, since 'quantity in area' is rarely involved. However, one example of such a map was compiled and drawn by R. E. Murphy and H. E. Spittal,[1] which was intended to show 'coal-mining intensity' in terms of tons per square mile on a county basis. The average density was calculated for each county in the Appalachian bituminous coal region, regardless of the fact that in many cases a portion of the county was known to be non-producing. Obviously such an industrial map is of limited value.

Transport Choropleths

Occasionally choropleth maps can be used for the maps showing the density of transport systems, where official returns of the length of routeway for each administrative unit are available. Such a map, however, is less revealing than an isopleth map, constructed as described above.

Quantitative Symbols

Dots

Perhaps the most convenient method of illustrating the distribution of some absolute agricultural figures is by means of dots, each with an identical value, placed within the boundaries of the administrative areas to which they refer. The chief objection is that yields and numbers per unit of area are not accurately shown, although a reasonable visual impression of density of distribution is given for stock; thus if two counties have the same number of cattle, but one county is twice as large, then the density of the dots will be half as great (Fig. 109). Geographical factors can be allowed for when placing each dot to give a subjective impression (see p. 21).[2]

Dots can be used very effectively when plotting values in detail on a large scale. E. R. Payne, for example, drew a most detailed dot map

[1] R. E. Murphy and H. E. Spittal, 'A New Production Map of the Appalachian Coal Region', *Annals of the Association of American Geographers*, vol. 34 (Lancaster, Pa., 1944).

[2] There are many striking examples in the various county volumes of the Land Utilisation Survey, and in L. D. Stamp (*op. cit.*), while the *Agricultural Atlas of England and Wales*, published by the Ordnance Survey (Southampton, 1932), makes extensive use of the method.

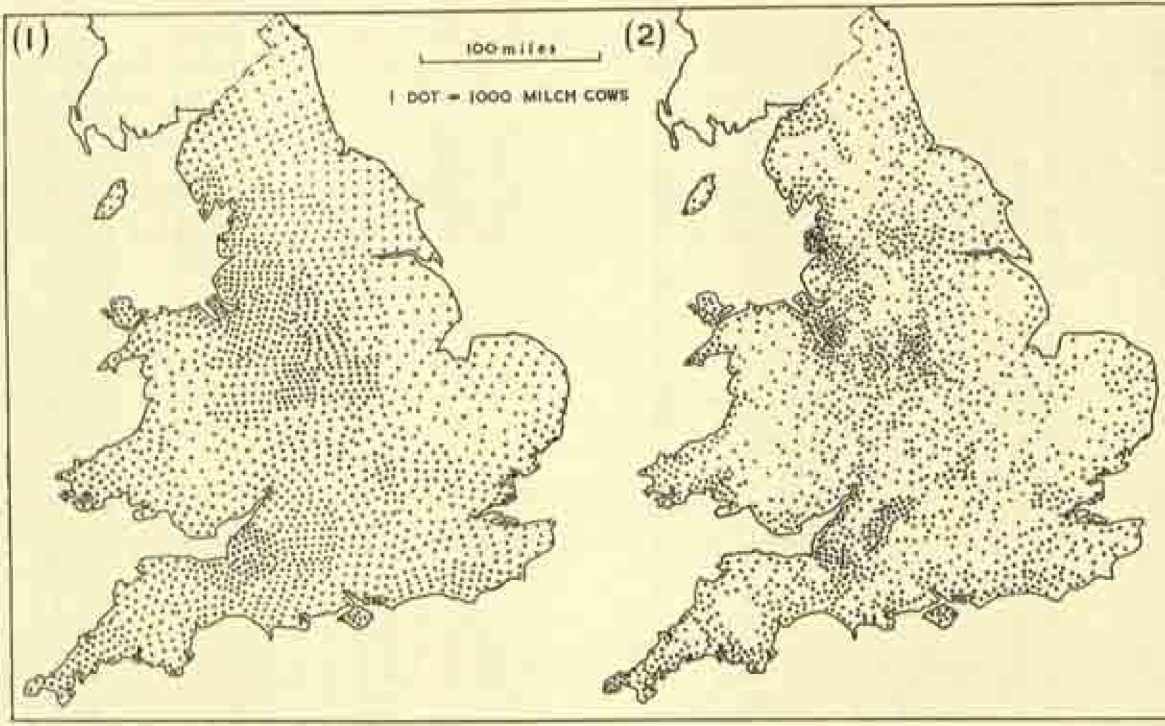


FIG. 109. TWO METHODS OF PLACING THE DOTS ON A DISTRIBUTION MAP

The data were obtained from Ministry of Agriculture and Fisheries, *Agricultural Statistics, 1930* (London, 1931).

On the left-hand map, the dots are placed objectively, so that they are evenly spaced within each county (or county division).

On the right-hand map, the dots are placed subjectively. An attempt has been made to show geographical distribution by taking into consideration factors of relief and land utilization as far as the scale allows.

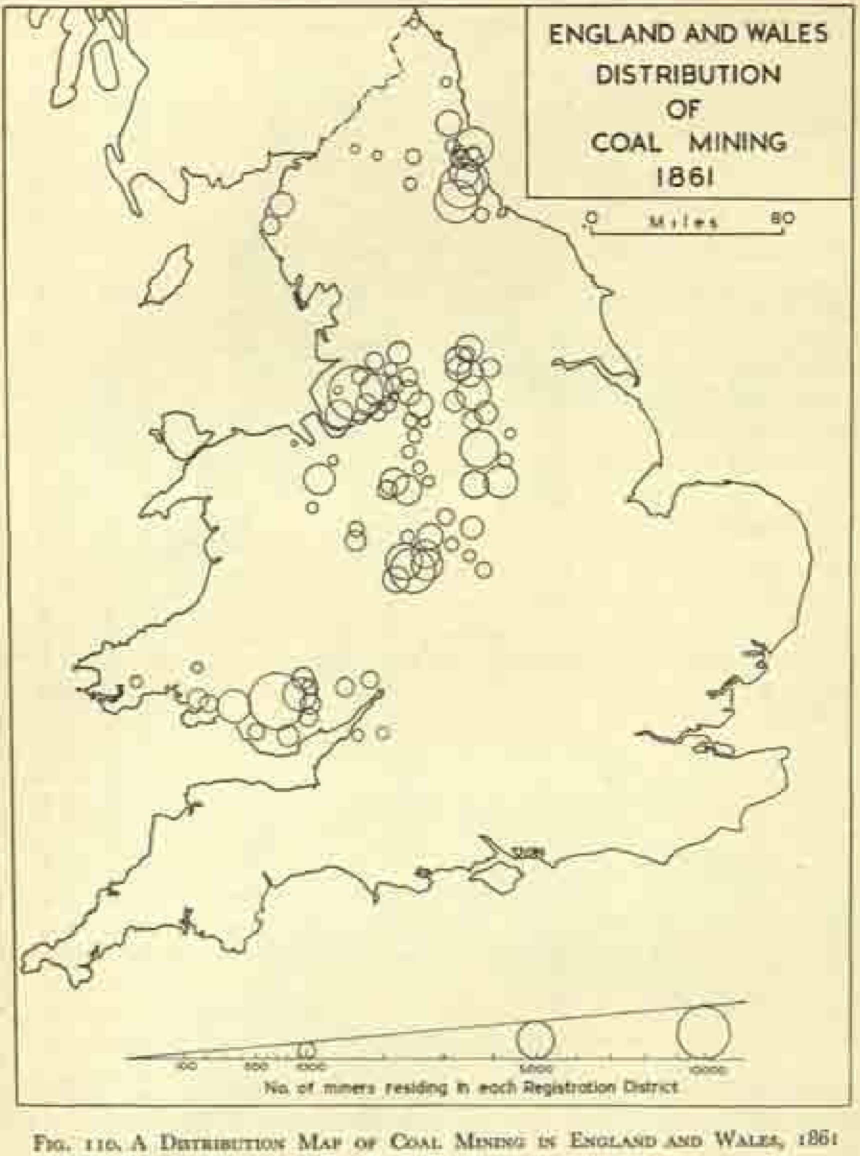


FIG. 110. A DISTRIBUTION MAP OF COAL MINING IN ENGLAND AND WALES, 1861

The data were obtained from *Census of England and Wales 1861: Appendix to the General Report* (London, 1863).

of the Market Harborough-Rugby area, on which each dot represented 10 animals, based on the 1935 returns for each parish, and another map to show the acreage of arable land, on which one dot represented 5 acres.[1]

'Mille' Maps. L. D. Stamp used a variation of the dot principle to emphasize changes in spacial distributions between two dates.[2] He called these 'mille' maps, because each map bears 1,000 dots, each dot therefore representing 0·1 per cent of the total. Thus one pair of maps compared the distribution of arable land in Britain in 1874 with that in 1938; on the first map each of the thousand dots represented 0·1 per cent of 18,089,000 acres, on the second each represented the same proportion of 11,861,000 acres.

Proportional Symbols

Proportional symbols are used very effectively to illustrate quantities which can be located specifically at a point. The exact location of the mine or factory can usually be found from a large-scale map or by an actual visit. Then the symbol must be chosen, whether square, rectangle, circle,[3] other geometrical figure, block-pile,[4] litteral,[5] or pictorial symbol, and the size or area of the symbol calculated in proportion to the quantity which it represents. A scale of symbols can be constructed, as shown in Fig. 9. The relative importance of the various mining areas in England and Wales in 1891, for example, is shown on Fig. 110 by means of open circles; it will be noticed that the relative importance of the mining districts is indicated in terms of the numbers of workers.

Quite apart from point locations, proportional symbols can be placed on a map within the administrative region to which they refer. Fig. 112, for example, denotes the output of French coal on a *département* basis by means of proportional squares; this should be compared with the accompanying Fig. 111, which shows non-quantitatively the geological extent of the several fields. Again, Figs. 113 and 114 use proportional discs, together with arrows to show not the actual routes (which would be virtually impossible) but the countries of origin and destination;

[1] E. R. Payne, *op. cit.*

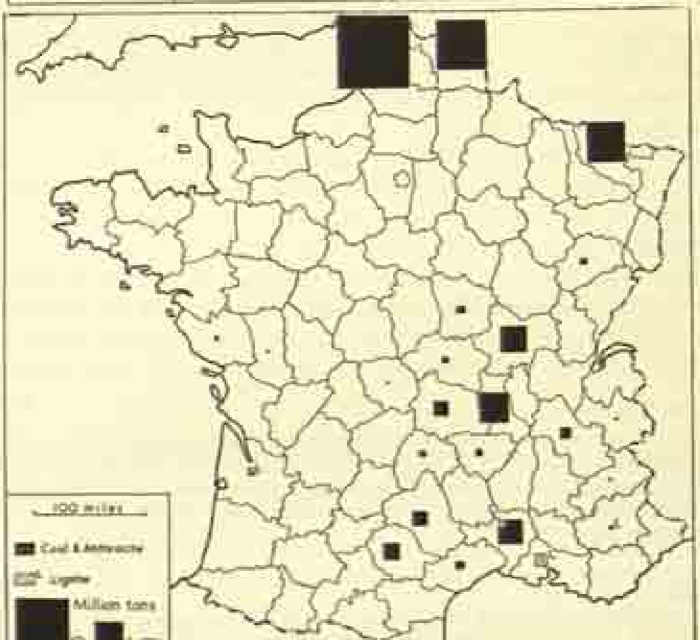
[2] L. D. Stamp, *op. cit.* The pairs of maps represented arable land (p. 102), permanent grass (p. 103), wheat (p. 104), oats (p. 105), cattle (p. 106) and sheep (p. 107).

[3] J. C. Weaver, 'United States' Malting Barley Production', *Annals of the Association of American Geographers*, vol. 34 (Lancaster, Pa., 1944), which employs dots and circles of various sizes.

[4] See E. Raisz, 'Geographical Distribution of the Mineral Industry of the United States', *Mining and Metallurgy* (New York, 1941), in which he devotes six plates to block-pile illustrations.

[5] For a striking example of this method, see G. B. Cressey, *China's Geographic Foundations*, p. 108 (New York, 1934), where minerals are denoted by initials which are drawn approximately proportional to the square root of the value they represent.

Nord
Moselle
Burgundy
St. Etienne
La Mure
Décazeville
Alès
100 miles
Coal & Anthracite Fields
Lignite Fields



100 miles
Coal & Anthracite
Lignite
Million tons

together they strikingly demonstrate the complicated interdependence of European heavy industry.

Symbols are less valuable for agricultural distributions, since point locations are rarely involved, except for such features as co-operative dairies or beet-sugar refineries, which are really industrial distributions. Proportional symbols placed within an administrative unit can be used for totals of animals, but should not as a rule be employed for total crop yields, since yields per unit of area, which are more significant than absolute totals, are not indicated. Axel Sömme drew an interesting map of the present importance and recent development of the transhumance of milch-cows in southern Norway.[1] Two contrasting symbols were used, one to represent an increase of 100 cattle on each *seter* between 1907 and 1938, a second to represent a similar decrease.

Line-Graphs

Line-graphs, either simple, multiple or compound, may be used to show absolute or percentage values of agricultural or industrial output, freight transport, trade statistics and so on, over a period of time. On Fig. 115, the absolute tonnages conveyed on the three sections of the Albert Canal in Belgium are graphed over a number of years, while on the right-hand graph the corresponding values in ton-kilometres (see p. 176) are shown for comparison. Absolute and percentage figures of the quantities involved may be placed on the same graph, using different weights of line and an absolute scale on the left side of the graph, with a percentage scale on the right; thus a graph of coal output of the southern and northern basins of Belgium from 1917 to 1946 is rendered all the more useful if the rapidly increasing proportion of the total contributed by the northern field is emphasized by a superimposed percentage graph. Fig. 116 is a compound graph, used to analyse the total and individual outputs of the seven collieries in northern Belgium from 1919; as each colliery came into production, its output was added in the form of another graph-line, and the section was shaded distinctively.

Semi-logarithmic graph-paper can be used to show rates of change of

[1] A. Sömme, 'Norwegian Agriculture and Food Supply', *Geography*, vol. 35 (London, 1950).

Figs. 111, 112. A Chorochromatic Map of French Coalfields (above) and Output of Coal Mining by Proportional Squares (below)

The boundaries of the exposed coalfields on the upper map were extracted from the *Atlas de France*, Plate 7 (Paris, 1939).

The output of coal from each *département* was taken from the *Statistique de l'Industrie Minérale, 1936* (Paris, 1938).

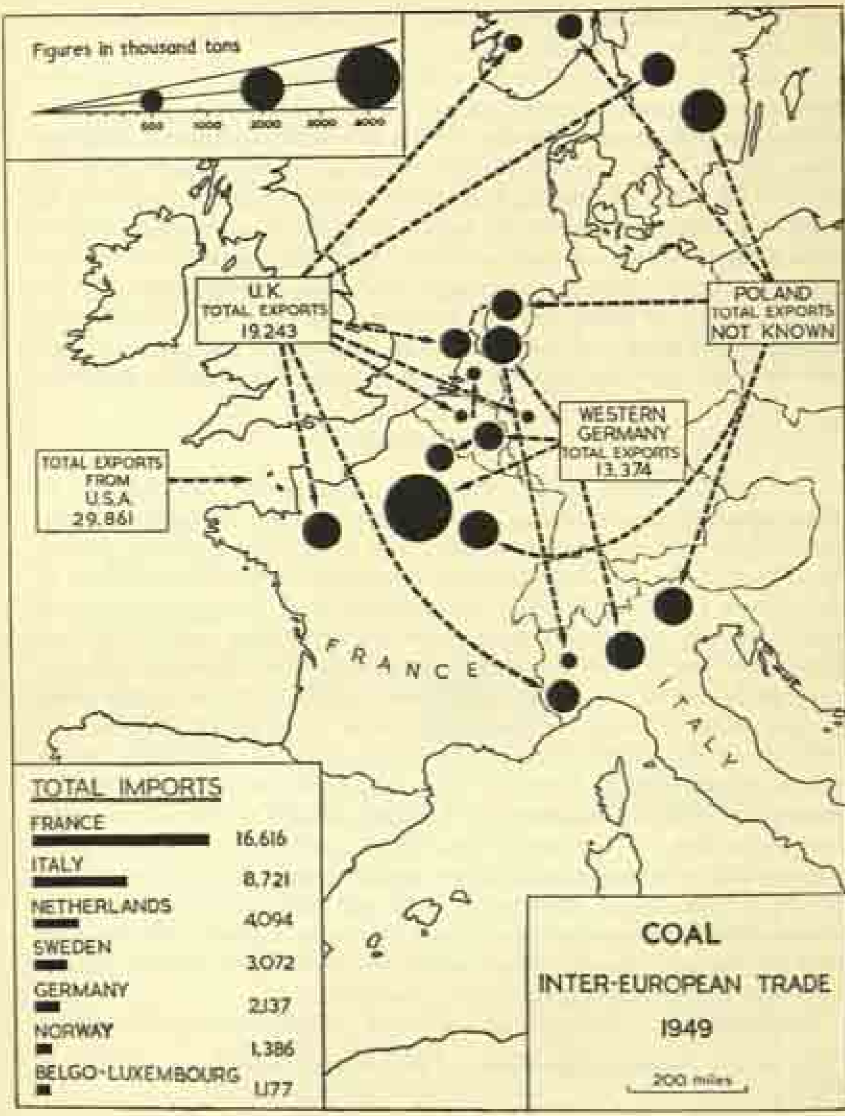


FIG. 113. A SYMBOLIC MAP TO ILLUSTRATE THE SOURCES AND DESTINATIONS OF COAL IN INTER-EUROPEAN TRADE, 1949

Based on data supplied by the British Iron and Steel Federation.

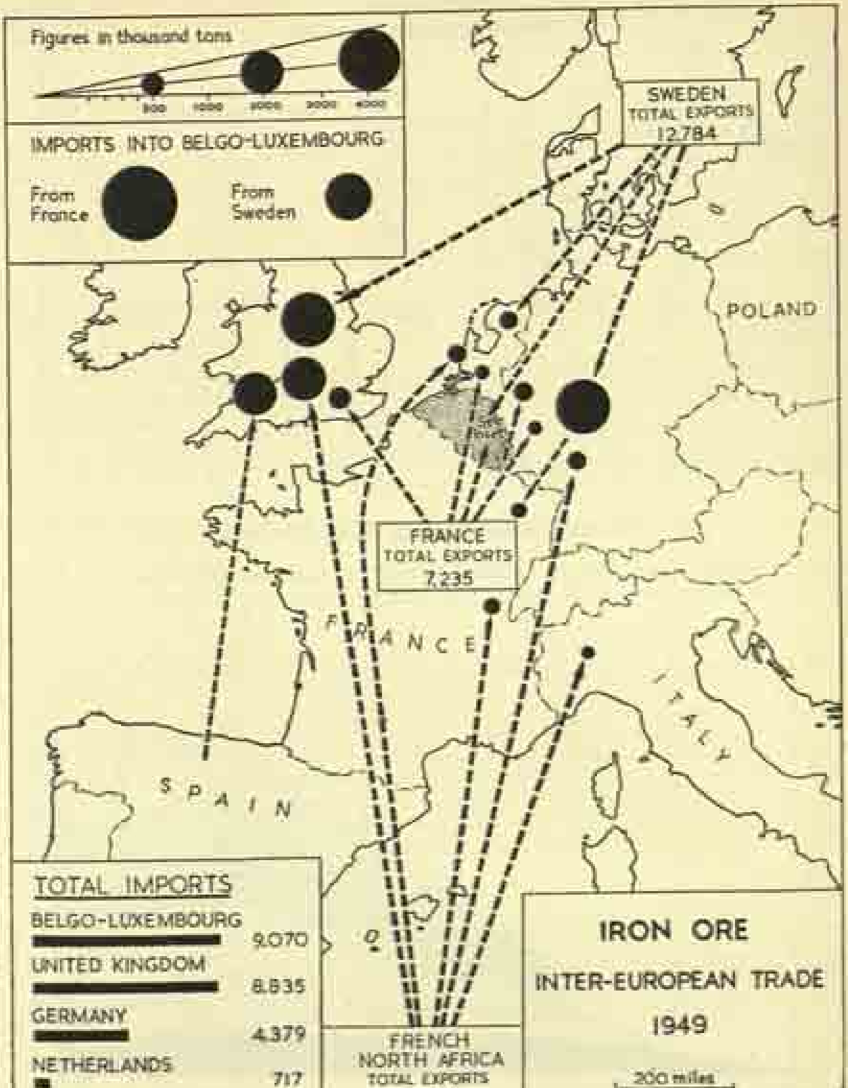


FIG. 114. A SYMBOLIC MAP TO ILLUSTRATE THE SOURCES AND DESTINATIONS OF IRON ORE IN INTER-EUROPEAN TRADE, 1949

Based on data supplied by the British Iron and Steel Federation.

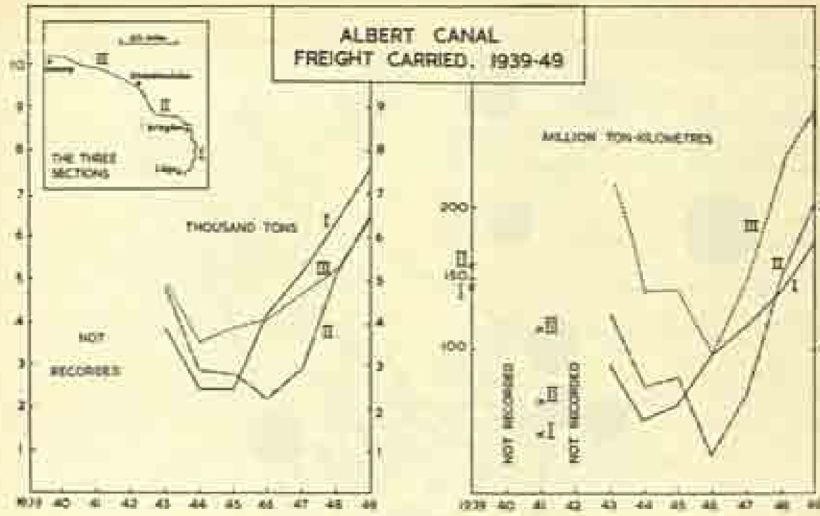


FIG. 115. POLYGRAPHS OF CANAL TRAFFIC

Based on data supplied by the *Institut National de Statistique* (Brussels). The figures refer to the three sections of the Albert Canal, as shown on the inset map.

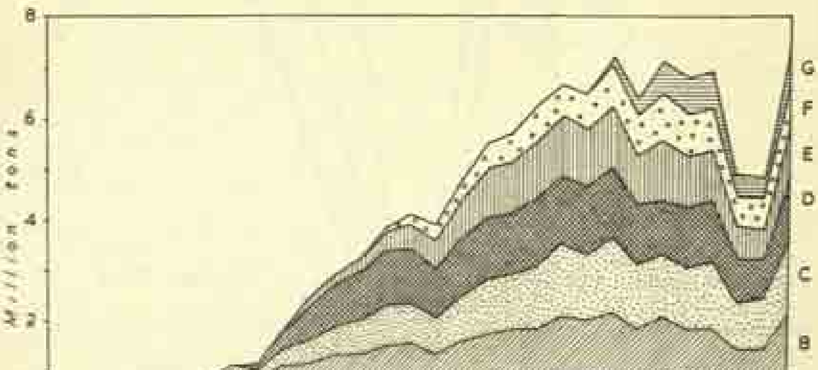


FIG. 116. A COMPOUND GRAPH OF COAL OUTPUT FROM THE KEMPENLAND COLLIERIES, 1917–46

Based on data obtained from successive volumes of the *Annales des Mines* (Bruxelles).
The collieries are shown in chronological order of production, as follows: **A.** Winterslag; **B.** Beringen-Koersel; **C.** Eisden; **D.** Waterschei; **E.** Zwartberg; **F.** Helchteren-Zolder; **G.** Houthalen.

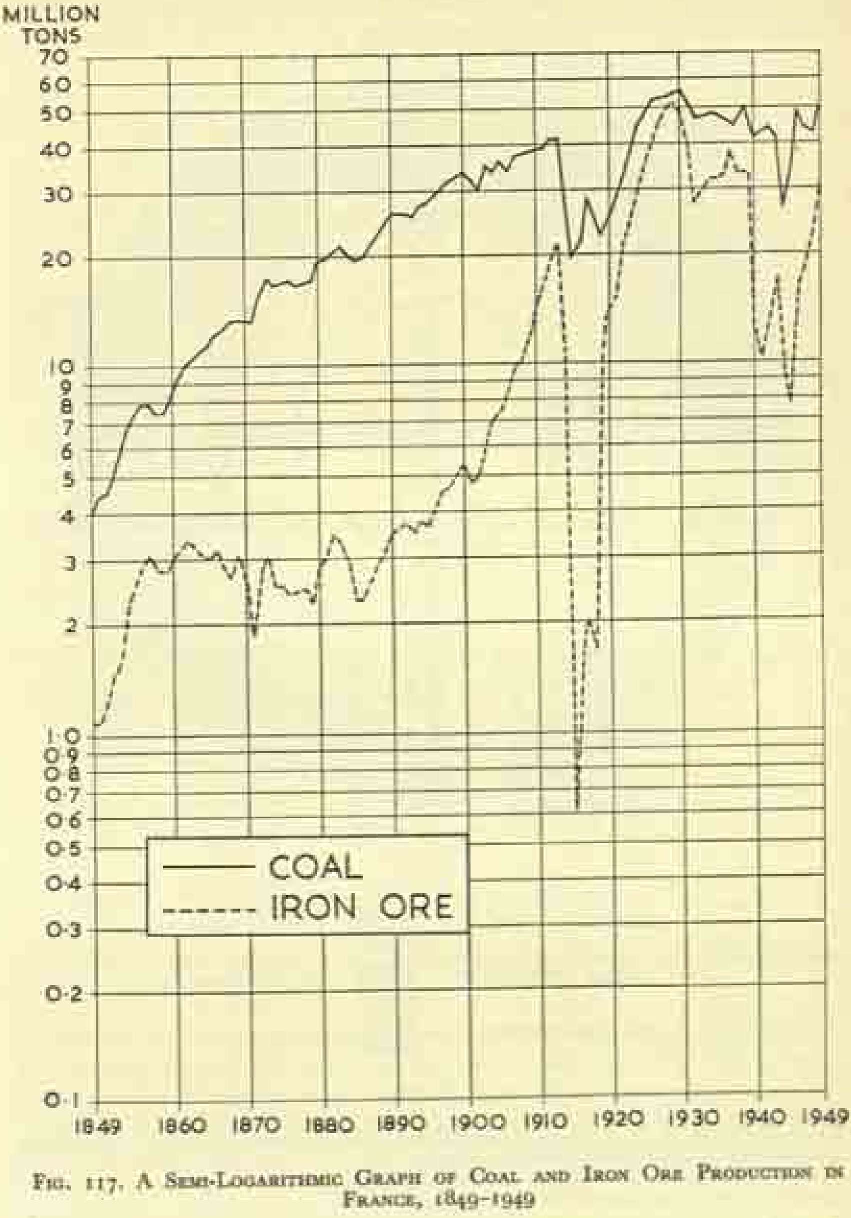


FIG. 117. A SEMI-LOGARITHMIC GRAPH OF COAL AND IRON ORE PRODUCTION IN FRANCE, 1849–1949

Based on *Annuaire Statistique, Résumé Rétrospectif*, 1946, and subsequent volumes (1947–9) of the *Annuaire Statistique* (Paris, annually).

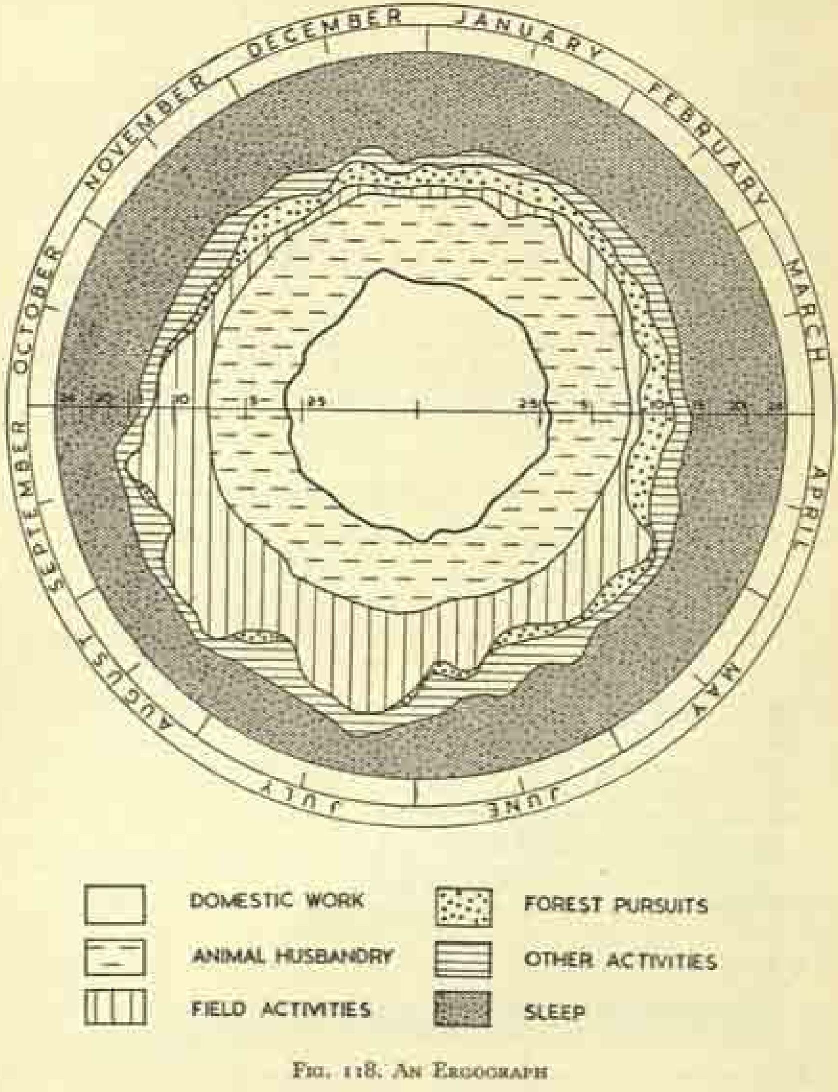


FIG. 118: AN ERGOGRAPH

Compiled by W. R. Mead, from statistical data derived from M. Sipilä, *Maatalouden työajankäyttö ja työntutkimus* (Helsinki, 1946).

This diagram has been drawn to show employment of working hours on a weekly basis for a group of sample farms in Finland.

output, or where the range of absolute values to be represented is considerable. Fig. 117 graphs on three-cycle paper the output of French coal and iron ore for a century, from 1849 until 1949. The range of absolute figures for coal production is from 4 million tons in 1849, to a maximum of 55,057,000 tons in 1930. Not only are the widely

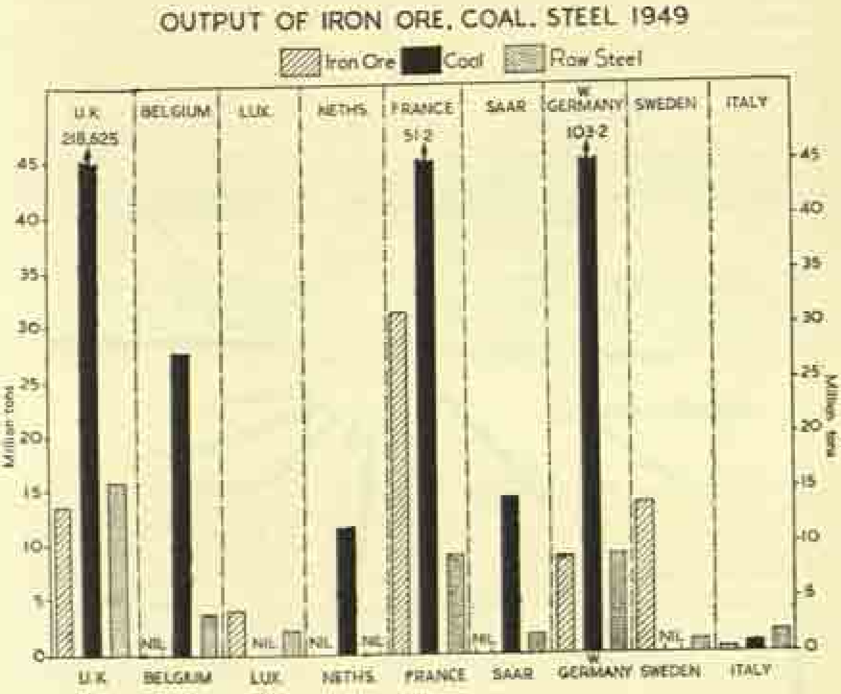


FIG. 119. THE OUTPUT OF COAL, IRON ORE AND STEEL BY COLUMNAR DIAGRAMS, FOR NINE EUROPEAN COUNTRIES, 1949

The statistics were obtained from the *Statistical Year-Book of the United Nations Organization, 1949* (New York, 1950).

fluctuating trends of production accurately presented, but the result is of manageable size; a graph of the same quantities on an arithmetic scale, allowing one inch of vertical scale to 100,000 tons (i.e. the length of the lowest division of the log-scale used) would be over four feet in length.

Ergographs

Ergographs, or curves showing the amount of work done at various times of the year, is a term coined by A. Geddes and used by A. G.

Ogilvie in a paper on regional techniques.[1] The information can be plotted as a curve showing the amount and nature of work done each month, either in the conventional Cartesian manner,[2] or more properly in the form of a circular compound graph (Fig. 118). This circular form is well adapted to show the continuous rhythm of seasonal activities.

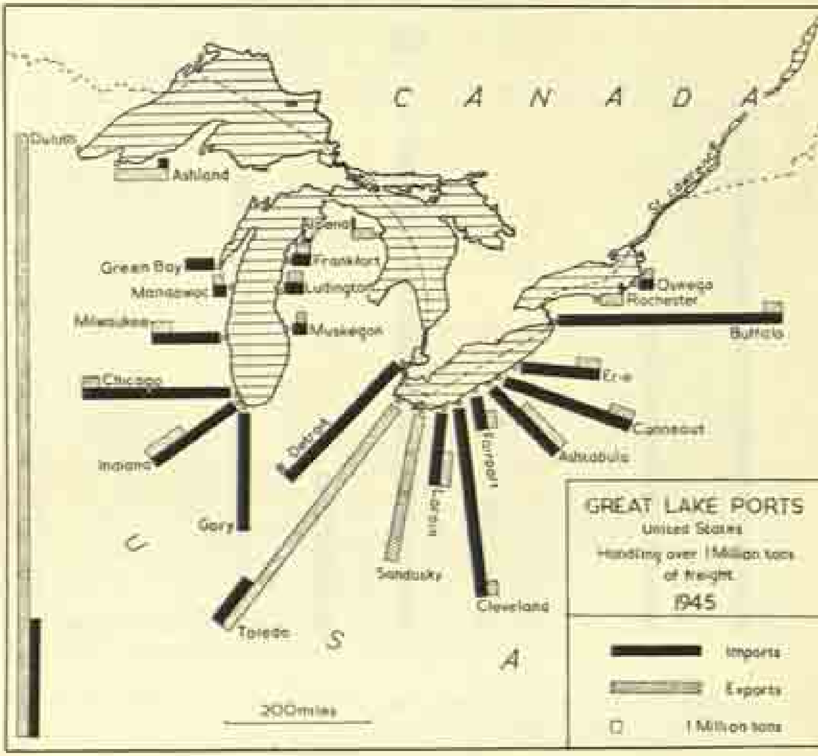


Fig. 120. Located Bar-Graphs of Freight Handled by the Great Lake Ports, 1945

The data were obtained from *Statistical Abstract of the United States* (Washington, 1946).

Columnar Diagrams

Columnar diagrams, or bar-graphs, also have a wide use in representing economic statistics, and in fact are perhaps the most frequently used economic diagram. Fig. 119 is a three-fold bar-graph, drawn to

[1] A. G. Ogilvie, 'The Technique of Regional Geography with special reference to India', *Journal of the Madras Geographical Society*, vol. 13, p. 121 (Madras, 1938).

[2] See examples in A. Demangeon, 'France Economique et Humaine', pp. 2-5, *Géographie Universelle*, vol. 6, part 2 (Paris, 1946).

summarize the output of iron-ore, coal and raw steel in 1949 for nine European countries, which reveals the critical shortages in some of these countries. A simple form of horizontal bar-graph, representing merely a total figure, is used in the insets on Figs. 113, 114 to supplement the information on the maps themselves. Bar-graphs may also be placed conveniently on a location map; thus Fig. 120 summarizes the freight handled by the Great Lake ports in 1945. The base of each double column was placed as near as possible to the port it represents, and a distinction was made between imports, the column

FIG. 121. DIVIDED RECTANGLES TO SHOW LAND UTILIZATION IN CUMBERLAND AND KENT

The data were obtained from Ministry of Agriculture and Fisheries, *Agricultural Statistics, 1939* (H.M.S.O., 1940).

representing which was filled in black, and exports, represented by a stippled column. One can see immediately the vast exports of Duluth from the ore-fields of the Superior region, and the corresponding imports of the ore by the Erie ports to serve the Lake-side and Pennsylvanian industrial areas.[1]

DIVIDED RECTANGLES AND CIRCLES

Divided Rectangles

Divided rectangles may be drawn, like bar-graphs, proportional in length to the values they represent, or, where comparisons are involved, two or more identical rectangles may be divided on a percentage basis. Fig. 121 compares the land utilization in two counties, Cumberland and Kent, of nearly similar size; the diagrams bring out the striking contrasts one would expect, but in addition there are some rather unexpected similarities. Fig. 122 uses divided rectangles, analysing

[1] Compare A. G. Ballert, 'The Coal Trade of the Great Lakes and the Port of Toledo', *Geographical Review*, vol. 38 (New York, 1948), in which he analyses the coal trade of the Great Lake ports, using proportional circles to show shipments and receipts.

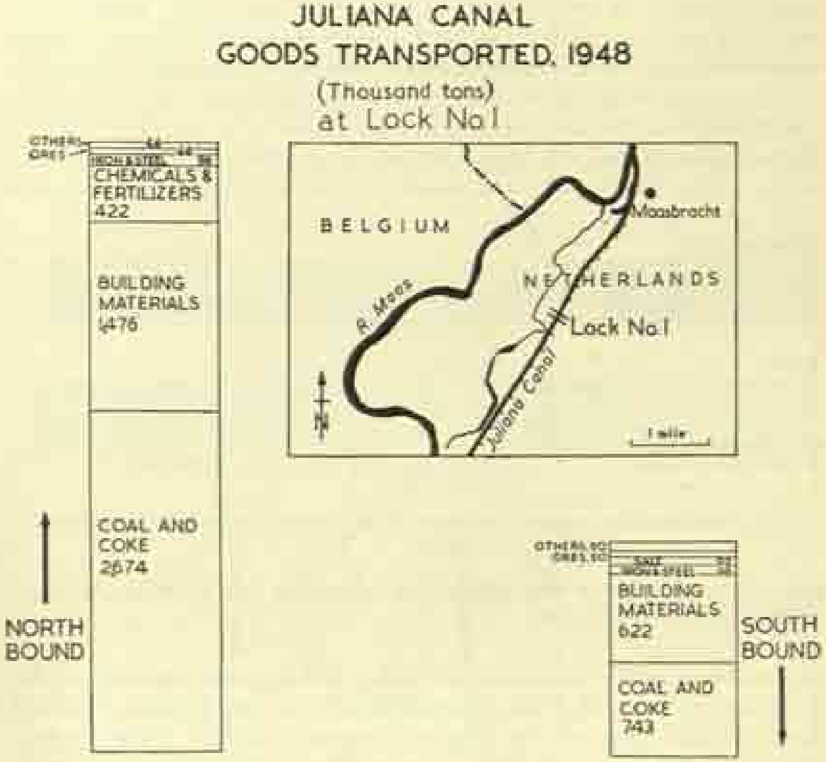


FIG. 122. DIVIDED RECTANGLES TO SHOW FREIGHT TRANSPORTED ON THE JULIANA CANAL, 1948

The data were obtained from the *Centraal Bureau voor de Statistiek* at The Hague.

The Juliana Canal was constructed to by-pass the unnavigable section of the river Maas, as shown in the inset map, between Maastricht and Maasbracht. The position of Lock No. 1, at which the freight figures were recorded, is indicated.

The north-bound freight totalled 4·8 million tons in 1948 (cf. 6·8 million tons in 1938); the importance of the canal in the exploitation of the South Limburg coalfield is shown by the high proportion of coal and coke in the freight figures. The south-bound freight totalled 1·7 million tons in 1948 (cf. 0·7 million tons in 1938).

north- and south-bound freight on the Juliana Canal in 1948, in conjunction with a location map, which depicts the exact lock at which the freight returns under consideration were recorded. There are many published examples of divided rectangles. Hartshorne and Dicken delimited[1] six type-regions based on crop and livestock associations. For each region, they constructed divided rectangles to illustrate the

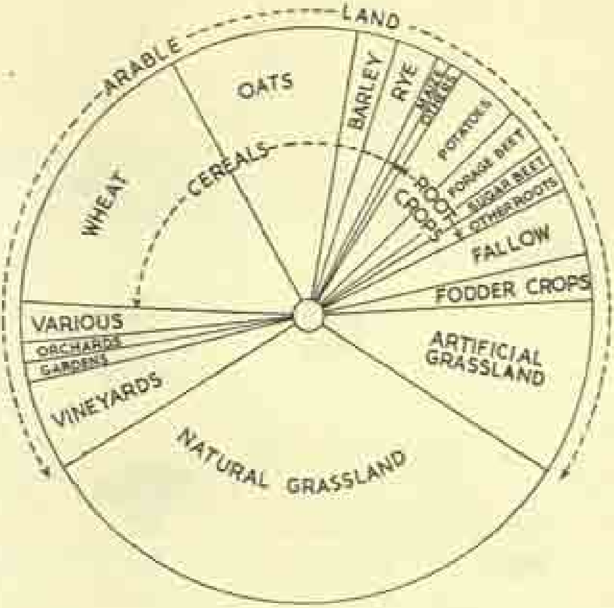


FIG. 123. AN INDIVIDUAL DIVIDED CIRCLE TO SHOW THE UTILIZATION OF FRENCH AGRICULTURAL LAND, 1938

The data were obtained from the *Statistique Agricole Annuelle* (Paris, 1939).

crop and livestock proportions. In the European examples, the crop rectangles were made the same length and divided on a percentage basis, while the livestock rectangles were made proportional to the number of animal units per 100 acres of cropland. In the American examples, the same principles were used, except that a triple rectangle was used to indicate the extent of arable, pasture and woodland, the length of which was uniform for every example, but the width of each was made proportional to the actual acreage involved.

[1] R. Hartshorne and S. N. Dicken, 'A Classification of the Agricultural Regions of Europe and North America on a Uniform Statistical Basis', *Annals of the Association of American Geographers*, vol. 25 (Lancaster, Pa., 1935).

Divided Circles

The utilization of agricultural land in France is analysed on Fig. 123 by means of an individual circle; no statistics have been added owing to the crowded nature of the lettering, but even so the diagram is quite revealing. Fig. 124 uses divided circles to show the utilization of the

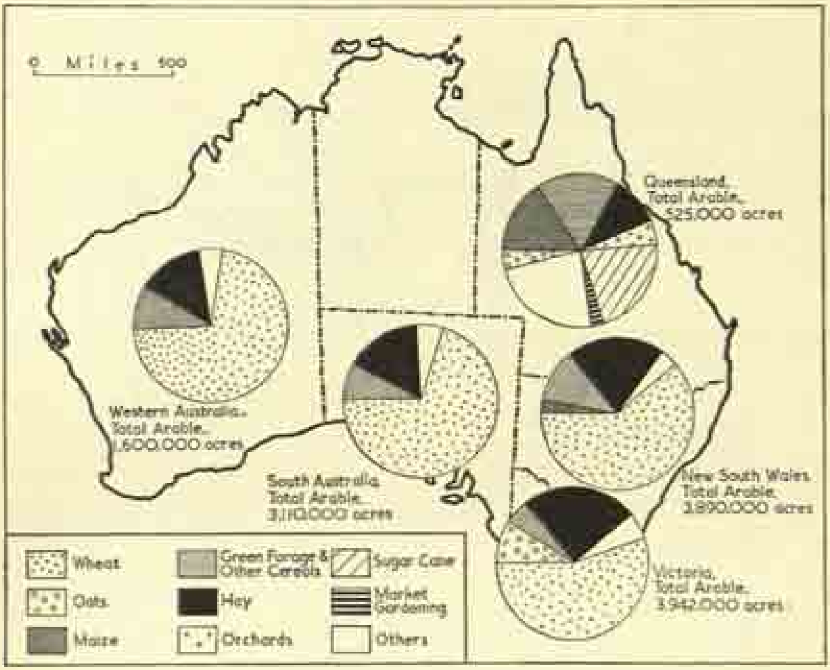


FIG. 124. LOCATED COMPARABLE DIVIDED CIRCLES TO SHOW AGRICULTURAL LAND IN AUSTRALIA, 1947

The data were obtained from the *Official Year-Book of the Commonwealth of Australia* (Canberra, 1948).

The dominance of wheat in every state but Queensland is immediately apparent, while in that state sugar-cane and maize are much more important. One point to note is that the category 'Orchards' appears in the circle for Queensland, but is absent in the others where it actually occupies a greater absolute area; its percentage area was, however, so small in these states that it could not be separately distinguished, and had to be included in the composite category of 'Others'.

arable land in each of the five Australian states; no attempt has been made to draw the circles proportional to the totals, which are lettered below each. The difference between the smallest area involved (i.e. Queensland) and the largest (Victoria) is so great that the eye would find it difficult to compare the areas of the sectors in each, although

it is relatively easy to compare the proportions when the circles are of equal size. In Fig. 125, however, it was essential to indicate the total numbers of workers at each colliery to represent the relative importance of that colliery in the East Glamorgan coalfield; only two divisions

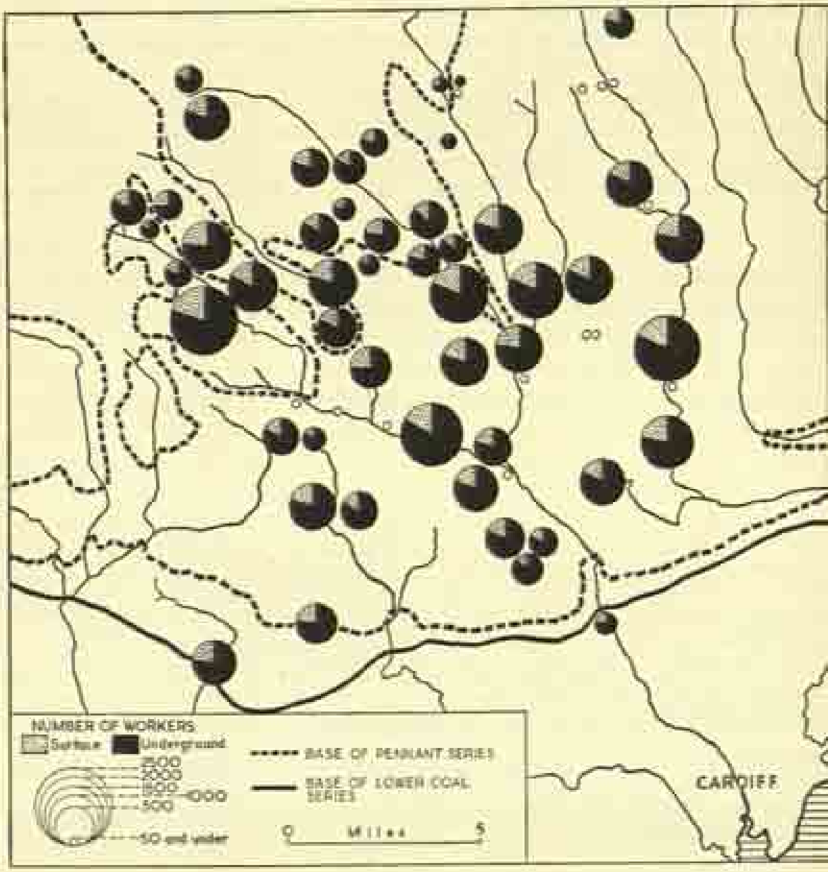


FIG. 125. LOCATED DIVIDED CIRCLES TO SHOW PERSONS EMPLOYED AT THE COLLIERIES IN THE EAST GLAMORGAN COALFIELD, 1948

The data were obtained from the Ministry of Fuel and Power, *List of Mines in Great Britain and the Isle of Man* (London, 1949).

No differentiation is made between surface and underground workers where less than 50 persons were employed at a colliery.

were necessary, between surface and underground workers, and it was therefore permissible to use proportional circles.

Three examples from the very large number available in publications will serve to illustrate the value of divided circles in illustrating

distributions. L. S. Wilson uses forty-five individual diagrams to show the nature and direction of Latin-American foreign trade.[1] L. D. Stamp employs a series of three-sector divided circles superimposed on a county map of Great Britain, to show the proportions of permanent grassland, tillage and temporary grassland in each county and for Great Britain as a whole between 1937 and 1944.[2] The two

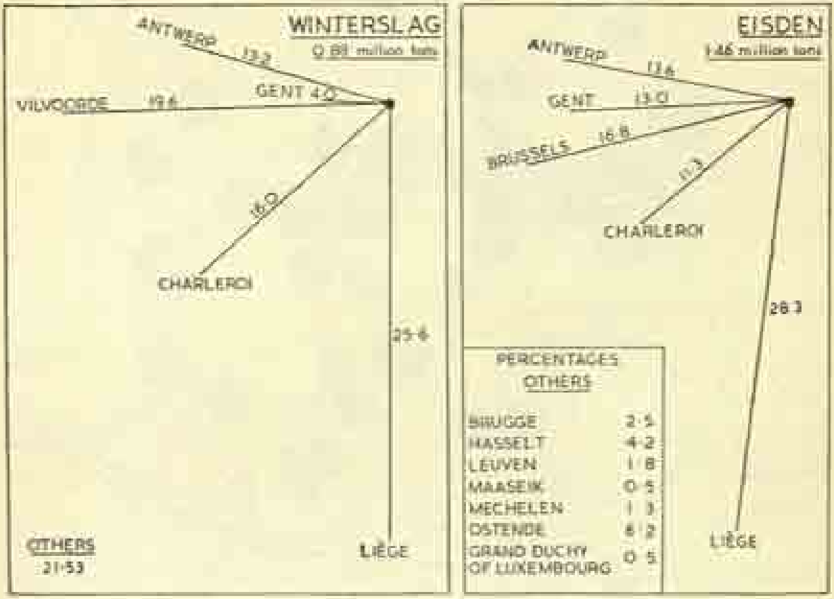


FIG. 126. STAR-DIAGRAMS OF COAL MOVEMENT FROM TWO BELGIAN COLLIERIES, 1948

The data were obtained from the *Association Charbonnière de Bassin de la Campine* in Hasselt.

The two collieries, Winterslag and Eisden, are in the new Kempen coalfield in north-eastern Belgium.

maps summarize most effectively the results of war-time ploughing. A series of located divided circles was used to show the output and movement of coal from the Kempen field of north-eastern Belgium, analysing the amounts which moved from each colliery by road, rail and water as a proportion of the total output of each.[3]

[1] L. S. Wilson, 'Latin-American Foreign Trade', *Geographical Review*, vol. 31 (New York, 1941).

[2] L. D. Stamp, *op. cit.*

[3] F. J. Monkhouse, 'Coal Movement in Belgium, with Special Reference to the Kempen Field', *Transactions and Papers, 1950: The Institute of British Geographers*, no. 17 (London, 1952).

STAR-DIAGRAMS

Economic distributions may be illustrated by drawing lines, proportional in length to the values they represent, radiating in the approximate direction of movement, from the centre of output. Fig. 126, for example, illustrates the movement of coal from two of the large Kempen collieries, in which the radials indicate the approximate direction of movement, while the length of each is proportional to the amount involved. Such star-diagrams are of much less value, however, on a map than is a line of proportional thickness (see Flow-line maps, below).

Econographs

G. Taylor devised a type of star-diagrams, based on what he considered to be the four major controls of white settlement, namely, height above sea-level, rainfall in inches, temperature in °F and estimated reserves of coal in tons per square mile.[1] From a central point four axes were drawn, each proportional in length to these four features; the temperature control scale was given double the weight of the rainfall. By joining the ends of the four axes, a rectangular figure was produced, which he called an *econograph*. By comparison with a hypothetical figure representing 'optimum habitability', the shape of the econograph for any particular regions gives an immediate impression of the relative suitability of an area for white settlement, based on these criteria. The principle is akin to that of the climograph (see p. 163).

This type of econograph suffers from the fact that it takes into account only four criteria; in other areas, irrigation, hydro-electric output or oil production may be of greater importance to the habitability. It is possible to plot eight controls instead of four and so obtain representative octagons.

Further, by assuming 1,000 units to occupy the area of an ideal econograph, it is possible to calculate a number to represent proportionally the area of any other econograph. If the value of each is plotted, on an outline map in the geographical centre of the area it represents, isopleths can be drawn, to which Taylor gave the name of *isoiketes* (lines of habitability).

FLOW-LINE MAPS

Movement of commodities may be represented by various forms of 'dynamic' map. The uses of proportional circles, bars and star-graphs have already been discussed.

The term 'flow-line' map is used of a movement map which shows

[1] G. Taylor, 'The Distribution of Future White Settlement', *Geographical Review*, vol. 12 (New York, 1922).

the direction or route followed by means of a line representing the railway or waterway concerned, while the quantitative impression is conveyed by the width of the line. Thus Fig. 127 depicted the movement of coal along Belgian waterways in 1948, expressed in terms of ton-kilometres (see p. 176). Other values can be used, such as ton-kilometres per kilometre of waterway (Fig. 128), or absolute tonnage in terms of total loadings at points along each waterway or section of each waterway.

As a rule, there is rarely the sufficiently detailed information available to construct rail or road traffic-flow maps (see p. 176). Occasionally, however, unofficial figures for individual rail-routes can be obtained by patient inquiry; a map was constructed illustrating coal movement in 1949 by rail and water from the Kempen collieries, using information supplied by the seven collieries themselves.[1] In addition, service-frequency maps can be constructed; motor-bus[2] and train time-tables (including unofficial 'working' time-tables) can be analysed, and road-traffic censuses are occasionally available.

To construct a flow-line map, trace an outline in pencil of the actual routeways. Examine the maximum and minimum quantities involved, and, bearing in mind the complexity of the outline pattern, choose a scale of line thicknesses which can be fitted into the map without confusion. Thus, for example, 1 millimetre of line-width might represent 1 million ton-kilometres, and values would be represented for each waterway by lines of proportional width. Generalizing where necessary the sinuosities of the pattern, and using a pair of dividers, draw parallel lines on either side of the pencil outline, then fill in with black (Fig. 128). Instead of filling in the flow-lines in black, values may be more easily assessed at a glance by drawing a series of parallel lines along each waterway (Fig. 127). Thus, if one line represented 1 million tons, a value of 4·8 million would be shown by

[1] F. J. Monkhouse, *op. cit.*

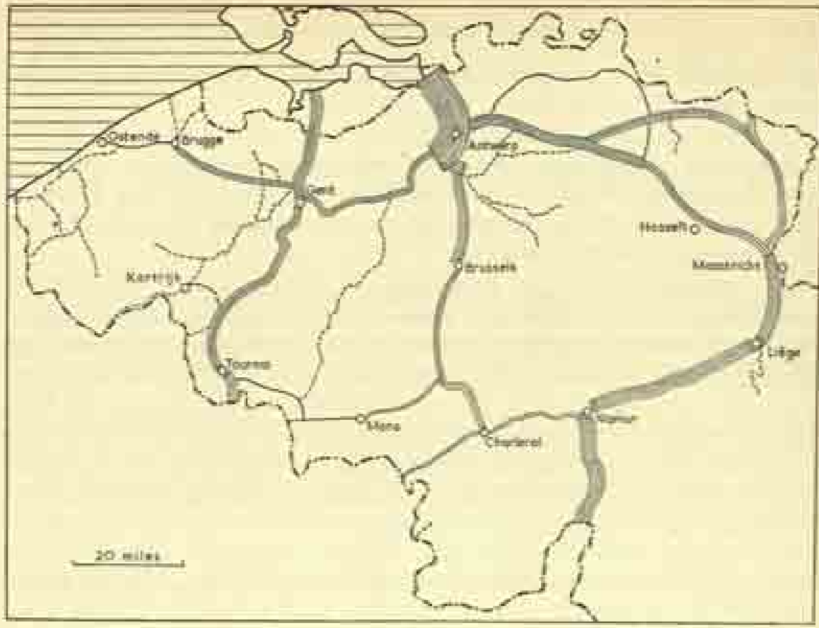
[2] F. W. Green, 'Motor-Bus Centres in South-West England', in *Transactions and Papers, 1948: The Institute of British Geographers*, no. 14, p. 60 (London, 1949); and 'Town and Country Services', in *Geography*, vol. 34, pp. 89–96 (London, 1949).

FIGS. 127, 128. FLOW-LINE MAPS OF BELGIAN COAL MOVEMENT, 1948

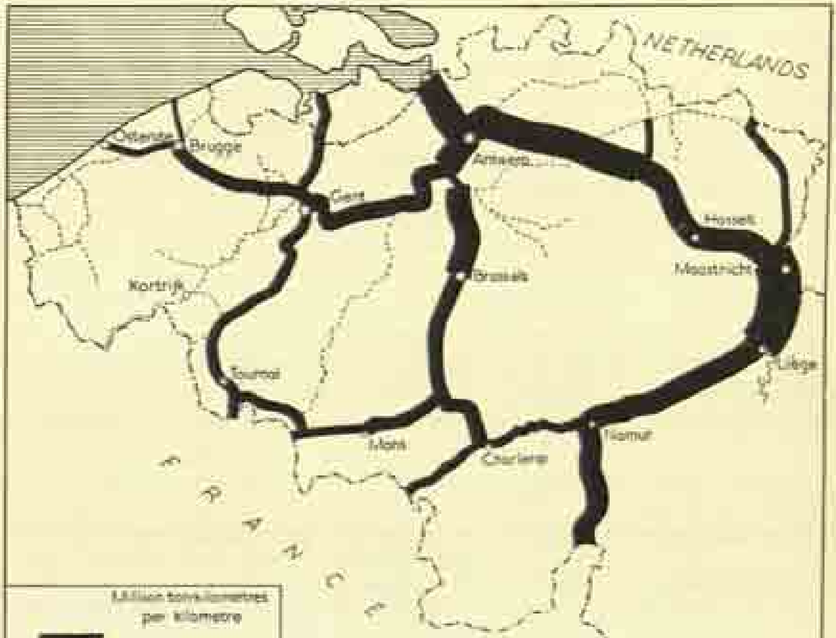
The data were obtained from the *Institut National de Statistique* in Brussels.

Fig. 127 (top) shows coal movement in ton-kilometres. Each single solid line represents one million ton-kilometres (to the nearest million), while a pecked line indicates an amount less than this figure.

Fig. 128 (bottom) shows coal movement in ton-kilometres per kilometre.



Ostende
Brugge
Gent
Antwerp
Hasselt
Maastricht
Kortrijk
Brussels
Liège
Tournai
Mons
Charleroi
Namur
20 miles



NETHERLANDS
Ostende
Brugge
Gent
Antwerp
Hasselt
Maastricht
Kortrijk
Brussels
Liège
Tournai
Mons
Charleroi
Namur
F R A N C E
Million tons-kilometres per kilometre
2·0
1·0
0·5
0·1
Less than 0·1
20 miles

five parallel lines; values under half a million tons could be represented by a pecked or dotted line.

A more elaborate type of traffic-flow map may be constructed by introducing refinements, such as a differentiation between upstream and downstream traffic[1] (for example, by a compound line in which the upstream value is dotted and the downstream value lined), or even between freight categories.

[1] See, for example, two maps in H. Ormsby, *France* (London, 2nd edition, 1950); one of these (p. 475) differentiates between upstream and downstream traffic in coal on the northern waterways, the other (p. 482) shows coal traffic on the Paris waterways.

CHAPTER V

POPULATION MAPS AND DIAGRAMS

Data

Data about population may be grouped for convenience into several major categories. One category comprises pre-Census sources such as the Domesday Book, Poll Tax and Hearth Tax records, and occasional individual estimates of population such as that made by Gregory King for England and Wales in 1695.[1]

A second category consists of the various national censuses, which constitute the chief source of information on the distribution and composition of the world's population. In Scandinavian countries and in eastern Canada, censuses were taken in the middle of the eighteenth century, while in western Europe they originated for the most part about the beginning of the nineteenth century.[2] But there are still some parts of the world, for example, China, Abyssinia and Arabia, where a full census has never been taken. Also, census returns vary in form, in completeness and in accuracy from one country to another.[3] For the most part, they are held only once in ten years.

A third category includes records of vital statistics which are available for western Europe and for the United States since the middle of the nineteenth century, and occasionally before. Standards of reliability vary, and only comparatively recently has much vital information, now regarded as essential, begun to be recorded even in countries with well organized demographic institutions.

Data returned by international organizations such as the United Nations,[4] the International Labour Office and l'Institut International de Statistique form a fourth category. These institutions are largely dependent in the first instance upon national census offices for their information, but they play an important part in compiling data, in standardizing them and in making them accessible and so improving their comparability.

Miscellaneous sources may be grouped together in a fifth category.

[1] D. V. Glass, 'Gregory King's Estimate of the Population of England and Wales, 1695', *Population Studies*, vol. 3 (Cambridge, 1949–50).

[2] For a review of more recent censuses, see H. J. Dubester, *National Censuses and Vital Statistics in Europe, 1918–39* (Washington, 1947); and H. J. Dubester, *Catalog of the United States Census Publications* (Washington, 1950). See also J. D. Durand, 'Adequacy of Existing Census Statistics for Basic Demographic Research', *Population Studies*, vol. 4 (Cambridge, 1950).

[3] United Nations, *Population Census Methods* (New York, 1951).

[4] See United Nations Organization, *Demographic Year-Book, 1948* (New York, 1949).

Government inquiries into population problems in connection with planning for war and for peace yield important supplementary data on population. These reports, for example, include those published by the Royal Commissions on Population in Sweden and in Great Britain. Data provided by State Planning Boards and by the National Resources Committee in the United States, and by L'Institut National d'Etudes Démographique in France also come into this category.[1] The British National Register of 1939 and the British Family Census of 1946 deserve special mention. Also of importance are occasional censuses of production and distribution, returns of data based on National Health registrations and on ration-book registrations, returns of migrants made by the British Board of Trade, by the American Immigration Commission and by similar institutions in other countries. Sample surveys of population undertaken by individuals or state-sponsored are becoming increasingly important in providing reasonably accurate data which formerly could only be obtained by means of full-scale censuses.[2]

Mention should also be made here of regional monographs on population which constitute important secondary sources of information; data from many scattered sources are made available in them on a comprehensive basis.[3]

In spite of all the data available it must be pointed out that our knowledge of the history of the population of the world is still insufficient even for a full appreciation of general trends, which suffer because the relative novelty of accurate census-taking allows no very deep perspective. Nevertheless, in spite of certain deficiencies, the data available to the geographer are sufficient for him to build up a broad picture of the present population of the world, and more detailed perspective sketches of the population of certain countries like Britain, Belgium, France, Norway, Sweden and the United States. Finally, he must be content to recognize that his finished maps cannot be more accurate than are the data upon which they are based.

[1] See P. George, *Introduction a l'Etude Géographique de la Population du Monde*, Institut National de Etudes Démographique (Paris, 1951), for a list of research centres and for bibliographical references.

[2] See F. Yates, *Sampling Methods for Censuses and Surveys* (London, 1949), for a discussion, and for a good example, J. R. H. Shaul and C. A. L. Myeburgh, 'Provisional Results of the Sample Survey of the African Population of Southern Rhodesia, 1948', *Population Studies*, vol. 3 (Cambridge, 1948–49).

[3] Outstanding examples of such monographs are: (1) M. Huber, *La Population de la France* (Paris, 1938); (2) J. C. Russell, *British Medieval Population* (Albuquerque, 1948); (3) H. Gille, 'The Demographic History of the Northern European Countries in the Eighteenth Century', *Population Studies*, vol. 3 (Cambridge, 1948–49); (4) D. Kirk, *Europe's Population in the Inter-War Years* (Geneva, 1946). For bibliographical purposes see *Population Index*, published quarterly by the office of Population Research, School of Public Affairs, Princeton University and the Population Association of America Inc.

Totals and Areas

Population returns may be made on the basis of individual countries, of major administrative units such as states, provinces and counties, and of smaller units such as parishes, townships and communes. The smaller the enumeration area for which population figures are available, the more accurate is the mapping of the population likely to be without recourse to guesswork. The area of each enumeration unit is given in most census returns. This information is necessary in order to calculate population density and also to check any changes which may have taken place in the boundaries of enumeration units between censuses, for both population totals and administrative areas have to be related when trends in population growth are being considered. Some censuses contain base-maps showing the boundaries of the various enumeration units at the date when the census was taken. The lack of such maps in many census returns is a very serious handicap; for example, the absence of parish maps in the successive censuses of England and Wales necessitates much research into changes of parish boundaries before plotting can even begin (see p. 235).

Social Structure

Rural and Urban Populations. Largely because of environmental differences, rural society presents such a sharp contrast to urban society that in their analyses of population demographers always seek to differentiate between the two. Hence in modern censuses various attempts are made to classify population returns upon this dual basis.

It is necessary to stress the fact that different criteria are used by different census organizations to distinguish between rural and urban populations, and this practice vitiates comparability of the published statistics. In France, the United States and Japan the criterion is numerical; all communities with a population below 2,000, 2,500 and 10,000 persons in those countries respectively are classified as rural. Thus a community of 9,000 in Japan is regarded as rural, whereas in France and the United States it would be classed as urban. Moreover, in the case of each of these countries, the value of the classification is seriously reduced because it makes no allowance for suburban populations living on the fringe of big cities. In England and Wales the criterion for distinguishing between rural and urban populations is based on the arbitrary assumption that all persons enumerated in Rural Districts constitute the rural population.[1] In the U.S.S.R.

[1] Moreover, as A. Stevens points out in 'The Distribution of Rural Population in Great Britain', Publication no. 11, *Institute of British Geographers. Transactions and Papers* (London, 1946), within the rural population itself there is a further dichotomy. A distinction may be drawn between the "basic rural population engaged in producing from the land" and a "secondary rural population which is in part ancillary in the exploitation of the land and in part contributes rather to the welfare of the rural community" (p. 28).

the economic function of the community is used as a measure of its rural character, but even this system has its disadvantages. Probably the best solution of the problem to date is to be found in the Brazilian Census of 1940, in which returns of rural, suburban and urban populations have been made upon the basis of regions specially mapped for the purpose.

Education. Until recently the percentage of illiterate persons in the population has been the only index of educational status to be found in most census returns. In parts of Eastern Europe, in Asia, India, Africa and South America, returns of illiteracy are still important as measures of the social character of specific regions.[1] In the United States' census of 1940, a question on the number of years' schooling was included in the schedule, which yielded invaluable information when the returns were cross-tabulated with those of race, age, sex and residence. A similar question was included in the Census schedule for the 1951 Census in Britain.

Housing Conditions. In certain of the censuses of England and Wales, details are to be found of the number of houses in each parish, together with information about the number of rooms per person. Similar data are given in the case of a number of European censuses, for example, that of Belgium. These data are likely to be enlarged in future censuses, so that these particular sections should prove invaluable in the analysis of inter-regional variations in living conditions.

Sex and Age Structure

Regional differences in the sex and age structure of population are very marked even within comparatively small regions like Lancashire, while in the world at large they are very considerable. A map showing the distribution of population, for example, may depict region *X* as having precisely the same density as region *Y*, but in region *X* the population may consist largely of old people and in region *Y* of young people. Similarly, region *X* may have many more women in its population than region *Y*. These differences are obviously of great significance. They are pointers to the vigour of the population, to its potential labour supply, to its powers of replacement and to its demographic history, and, in fact, affect almost every human activity associated with the region. Information about these differences is vital also in the sphere of economic and social planning.

It is usual to give general information about the sex and age structure upon a quinquennial rather than upon an individual yearly basis. In national census returns, information about sex and age is often

[1] An attempt to deal systematically with these data on a comparable basis was made in the work of J. F. Abel and N. J. Bond, *Illiteracy in the Several Countries of the World* (Washington, 1929).

given for larger administrative divisions, but not always for the smallest enumeration areas; for example, British returns provide data for Urban and Rural Districts, but not for parishes.

Ethnic Structure

Race. Data concerning the racial structure of population are to be found in anthropological treatises rather than in census returns. Racial criteria as understood by anthropologists include: (*a*) certain physical measurements,[1] describing the form of the head, commonly expressed in the form of cephalic indices; (*b*) measurements of stature; (*c*) pigmentation; (*d*) hair form; (*e*) biometrical measurements, often expressed in the form of indices, for example, Karl Pearson's 'coefficient of racial likeness';[2] and (*f*) physiological characteristics, in particular blood-group composition.[3]

In some parts of the world where racial admixture has proceeded for thousands of years, constituent 'pure races', if they ever did exist, cannot be readily recognized, and racial characteristics are accordingly ignored in the census returns. This is the case for most of Europe. In other parts of the world where diverse racial stocks have not mixed to the same extent due to later settlement, some attempt is made to classify returns of population totals upon the basis of 'race'. For example, in the first United States census of 1790 a distinction was made between 'free whites' and 'coloured slaves', and in 1850 the classification was expanded to cover 'native whites', 'foreign-born whites', 'Negro' and 'other races'. In 1940 the racial dichotomy 'white', and 'non-white' was introduced, and 'non-whites' were further subdivided into Negro, American Indian, Chinese, Japanese, Filipino, Hindu, Korean, Polynesian and other Asian. Not all of these divisions are truly racial; they might be better described as socio-racial groupings. The tabulation of data under such headings is vitally necessary in countries where problems of fertility, social and economic status, selective migration and so on, are all related to 'racial' structure of the population.

Nationalities. In the many censuses taken in different parts of the world, returns are to be found which deal with the national structure of the population. The data they incorporate are not of equal merit.

[1] For a further discussion, see C. S. Coon, *Race of Europe* (New York, 1939).

[2] K. Pearson, 'On the Coefficient of Racial Likeness', *Biometrika*, vol. 17 (Cambridge, 1926), and P. Raymond, *Introduction to Medical Biometry and Statistics* (Philadelphia and London, 1940), chapter 6 of which is devoted to graphical methods of statistical representation.

[3] See A. Davis, 'The Blood Groups and the Concept of Race', Pts. I and II, *Sociological Review*, vol. 27 (London, 1935), and A. E. Mourant, 'The Use of Blood Groups in Anthropology', *Journal of the Royal Anthropological Institute*, vol. 77 (London, 1950).

Because ethnic groupings may in some cases have a particular social or political significance, returns of the strengths of ethnic groups are often weighted in favour of the group which finds itself in power. Moreover, the criteria used to measure national affinities vary from one country to another. In some cases they may be based on 'race' or what are believed to be racial characteristics, for example, skin-colour. In other cases, country of birth, language, religion or 'nationality' may be the test imposed for the purpose of classification. These data afford some measure of group affinities, as apart from any class distinctions which exist in the population. Under certain circumstances people speaking the same language, or of the same religion, or similar in race, may act together or feel themselves bound in allegiance to some common cause. Because ethnic differences cut across class distinctions, they have a regional significance which is of particular interest to the geographer.

The greatest problem in the mapping of such data arises from the unreliability and the complexity of the statistics which have to be used. So much social and political prejudice enters into their compilation, particularly in the case of European countries, that special methods have to be adapted to give an impartial picture of the distributions in any one region. It is often necessary, for example, to produce a series of maps to cover different viewpoints.[1] The geographer can do no more than plot the statistics available, but he must make sure that these are as complete as possible, and that all sources of information have been duly explored.

Occupational and Industrial Structure

Before these statistics can be mapped the categories have to be reduced to a manageable number. The first problem in the geographical analysis of occupational statistics is the wide range of occupations which have to be dealt with, and the variety of classifications which have been adopted in various census returns. The problems of classification and compilation of occupational and industrial population statistics, which are common to all census returns, are best illustrated by reference to the Censuses of England and Wales.

In the first Census of 1801, only three classes of occupations were distinguished. They were: (*a*) persons chiefly employed in agriculture; (*b*) persons chiefly employed in trade, manufacture or handicraft; and (*c*) other persons not comprehended in the two preceding classes. In 1841, 877 occupations were listed and grouped into sixteen classes. This system was extended in 1851 to include 17 classes and 91 sub-classes. These were redesignated Orders and Sub-orders in 1861, and

[1] H. R. Wilkinson, *Maps and Politics* (Liverpool, 1951).

this system of Orders has formed the basis of all subsequent Census returns of Occupations.[1]

In the same year, 1861, it was explained in the Appendix to the Report that in future it was by the nature of the products they created that persons were to be classified into occupations. Thus not the kind of work a person did, but the end-product of the industry he worked in was stressed. An example will make this distinction clear. Commercial clerks may be associated with coal-mining, shipping, insurance or with a host of other activities. Under the scheme of 1861, clerks in coal-mining were classified under coal-mining, clerks in shipping under shipping, and so forth. This scheme was subsequently modified. In 1881, for example, all commercial clerks were extracted from the various industries and tabulated under one heading—that of *Commercial Clerk*. Such modifications seriously reduced the value of the comparison between one set of census returns and another. By 1891, the 431 occupational divisions distinguished in 1861 had been compressed to 347, but by 1901 the number had risen again to 382, and by 1911 to 472.

The Twofold Classification. Before the Census of 1921, a decision was made to separate the returns formerly designated as occupational into two divisions, occupational and industrial. Thus in both that census and that of 1931, all employed persons were classified twice, first according to the type of work they did, i.e. their occupation, and second, according to the end-product of the industry in which they worked. In the *Occupation Tables* of 1921 about 30,000 occupations were distinguished, which were classified into 32 orders and some 600 sub-orders, and in the *Industry Tables* about 9,000 industries were distinguished, which were classified into 21 orders and some 400 sub-orders. The decision to have two independent classifications removed many of the anomalies to be found in the earlier occupational returns. Even so, the new Occupation Tables were not entirely satisfactory. The necessity of reducing 30,000 occupations to a limited number of orders compelled the classifiers in spite of their professed aims to fall back in the end on products rather than processes in their classification. This problem was recognized in the Report of 1931 which stated: "In the absence of full recognition of the fundamental difference between principles of grouping, classifications have been framed which although described as occupational, prove on examination to be largely industrial."

Place of Work and Place of Enumeration. A certain divergence between place of work and place of enumeration must always be considered when census returns of occupations and industries are being mapped.

[1] See H. R. Wilkinson, 'The Mapping of Census Returns of Occupations and Industries', *Geography*, vol. 37 (London, 1952).

Unfortunately, nearly all these are based on place of enumeration and not on place of work. As A. Stevens suggests: "The census, of course, is essentially a fiscal provision for the more certain taxing of the lieges. On sound predatory principle it traces the quarry to its lair. It would be a more useful demographic instrument in many ways if it located man at his desk or bench."[1] In the Census of England and Wales in 1921, an attempt was made to give some regional detail of industries based on place of work,[2] but in the Report of 1931 it was stated: "It is to be observed in regard to tables showing the areal distribution of industry that the areal classification is throughout based on the individual's place of enumeration and that this may not be the same as the area in which his place of business is situated. Information regarding the latter was not obtained in 1931, and its inevitable disregard may for some purposes introduce an element of incongruity." Great care is necessary therefore if these tables are to be used to analyse location of industry.

Socio-Economic Indices

Demographic Coefficients. In analysing tables of population data, indices which are designed to give a measure of population pressure in different regions are often found useful. Probably the simplest index of this type is obtained from the formula,

$$C=dR$$

where C represents the demographic pressure or demographic coefficient, d the density of population, and R the net reproduction rate.

This is a useful expression because it shows at a glance what future population densities might develop in different regions providing there were no migration, and were the current rates of mortality and fertility to remain unaltered. It helps to explain the building-up of population pressure and migration trends, and is of use too in the study of economic problems and of political relationships between states. In Figs. 138–9, for example, the actual density of population is compared with the replacement density at a distance of one generation, i.e. about 25 years. If replacement densities at two or more generations were employed, the differences in the build-up of the population would be even more striking. The differences at two generations distant are:

$$C=dR^2$$

Mortality and fertility do not, of course, remain constant for any length of time, but the maps may be instructive nevertheless.

[1] A. Stevens, *op. cit.*, p. 34. [2] *Industry Tables*, Table 4.

A similar coefficient was devised by J. Smolenski as follows:[1]

$$C = dt$$

where t represents the rate of natural increase per thousand inhabitants.

Comparative Density. Population pressure is not purely a function of density and replacement of population, because density of population is obtained by a consideration of the total area of the population unit. This area may vary in its capacity to support population according to its geographical character. Hence more refined indices have been designed to eliminate this anomaly and to illustrate *comparative density*. The simplest index of this type is expressed by the formula:

$$D = \frac{P}{S}$$

where D = comparative density, P = the total population and S = the total cultivable land.

But cultivable land in itself varies, according to position, soil and other factors. To consider all the implications and to express them satisfactorily in the form of a simple numerical index is a formidable undertaking, particularly as problems of optimum population remain as yet unsolved. However, it is possible to refine further the above index by weighting the figure for cultivable land.[2]

Natural Replacement

The rate at which a population replaces itself—the natural increase—is a central fact in population study. Regional differences in population replacement have an obvious geographical significance, because even within units of the size of an English county marked differences occur. To ascertain rates of natural increase, it is necessary to consult vital statistical records as well as census returns. The keeping of these records is now almost universal, but in relatively few countries are these sufficiently accurate or complete to give more than a superficial view of the natural growth of the population. In England and Wales, civil registration was introduced in 1837, although before this date parish priests had kept records of marriages, births and deaths. Even after registration was introduced, the returns were not always complete. Illegitimate births were often ignored altogether, and such important details as the age of the mother have only recently begun to be recorded.

[1] *Congrès International de la Population*, vol. 2, section A (Paris, 1938).

[2] A method of doing so is outlined by P. Vincent, 'Pression Démographique et Ressources Agricoles', *Population*, vol. 1 (Paris, 1946). The problem is also considered in relation to the location of rural population in Great Britain by A. Stevens, *op. cit.*

The *Crude Birth-Rate* is usually expressed as the number of children born per thousand of the population, obtained from the formula:

$$\frac{\textit{Number of Births}}{\textit{Total Population}} \times 1{,}000$$

The *Crude Death-Rate* is also expressed as an index—the number of deaths per thousand of the population obtained from the formula:

$$\frac{\textit{Number of Deaths}}{\textit{Total Population}} \times 1{,}000$$

This is not a very refined measure of mortality because the age and sex structure of the population is not taken into account in its calculation.

Natural Increase. Crude birth- and death-rates may be used to find the natural increase in the population. For example, the birth-rate for 1948 in England and Wales was 17·8, the death-rate was 11; therefore the rate of natural increase was:

$$17{\cdot}8 - 11 = 6{\cdot}8 \textit{ per thousand of the population}$$

The estimated population of England and Wales in 1948 was 42,750,000 and therefore the natural increase was:

$$42{,}750 \times 6{\cdot}8 = 290{,}700$$

Standardized Rates. The crude birth-rate is not a very good index of fertility because variations in the sex and age structure of the population are not taken into account in its calculation. A standardized birth-rate, in which age and sex anomalies are smoothed out by comparison with a hypothetical standard population, is a better gauge.[1] For

Population of U.S.A., 1940

	Crude Birth Rates	*Standardized Birth Rates*
Urban . .	16·8	15·8
Rural . .	18·3	19·5

example, the crude birth-rates in the United States for urban and rural population in 1940 are inaccurate measures of fertility, because the urban population contained a greater proportion of women than did the rural population. It may be seen from the above table that when allowances are made for this, the figures are very different.

[1] Procedures for standardization are discussed in, for example, T. L. Smith, *Population Analysis* (New York, 1948), and in P. R. Cox, *Demography* (Cambridge, 1950).

Fertility Ratios. Standardized rates are difficult to compute, however, and there is a more simple method of arriving at a good estimate of fertility by relating the number of young children in the population to the number of women of child-bearing age. This fertility ratio is usually expressed as:

$$\frac{\textit{Number of Children under 5 Years Old}}{\textit{Number of Women aged 15–50}} \times 1{,}000$$

It provides a simple index to fertility which can easily be mapped. The information necessary for the calculation is obtained directly from the tabular data recorded in various census returns, and in the case of Britain, from the *Registrar General's Estimates of Ages and Sexes in the Population*. It can moreover be extracted from quinquennial tables, which makes the calculation less laborious. Information about age and sex groups dating back to about the middle of the nineteenth century are to be found in most European census returns—in the case of England and Wales from 1841. Hence it is possible to produce maps showing distribution of fertility ratio for over a hundred years.

Net Reproduction Rate. A useful index to the rate at which a population is replacing itself is provided by the net reproduction rate, first demonstrated by R. R. Kuczynski.[1] He pointed out that excess of births over deaths was a deceptive measure of replacement, because many countries with a surplus of births over deaths were not actually replacing their populations. In other cases, the population increase was being maintained merely because older people were surviving longer. Kuczynski maintained that population replacement could only be effectively measured if a whole generation were put to the following test. Was the fertility and mortality in a population such that a generation, permanently subject to them, could during its own lifetime produce enough children to replace itself? Such a test could be devised by considering only female births. If a generation of mothers is successful in producing exactly the same number of mothers in the second generation, then it could be said to be exactly replacing itself. To take an example, the fertility tables for Australia, 1920–22, show that on the average a thousand mothers gave birth, during the whole span of child-bearing, to 1,517 female children. A reference to the mortality tables indicates that of these, 1,318 could be expected to become mothers. Hence 1,000 mothers had given birth to 1,318 future mothers. The population was replacing itself in the ratio of:

$$\frac{1{,}318}{1{,}000} = 1{\cdot}318$$

1·318 *being in this case the net reproduction rate.*

[1] R. R. Kuczynski, *The Measurement of Population Growth* (London, 1935).

The beauty of the net reproduction rate is its simplicity as a measure of replacement. If it is unity, the population is replacing itself; below unity it is failing to do so, above unity it is succeeding in doing so.

Male and Female Reproduction Rates. R. R. Kuczynski's concept of replacement of population as measured by female net reproduction rate only has been criticized recently, notably by P. H. Karnul.[1] He points out that in any actual population, two measures are available—female and male net reproduction rates respectively. An alteration of sex-age distribution caused, for example, by war will cause fluctuations in the male and female rates respectively, so that neither in itself may be considered as a sufficiently reliable index to population replacement, but both must be considered together.

Marriage Standardized Reproduction Rates. It may be useful occasionally to consider replacement rates as measured in the married population without reference to the unmarried females.[2] The necessary calculations are somewhat laborious, but they are of value in the analysis of the causes of differential fertility rates.

The Family Census of 1946. Regional variations in the size of the family, where such information is available over a long period, affords most important evidence on the replacement of population. In the *Royal Commission on Population* the results of the Family Census of 1946 were used as the basis of population projections rather than conventional analysis by means of age—specific fertility rates. Unfortunately, not much regional data on family formation and family building are at present available, but such data will probably be compiled in future censuses.

Migration and Movement

Growth of population is affected not only by natural replacement, but also by migration of population. Not only permanent migration of population has to be considered in the measurement of population characteristics, but movement of the population also. Some populations are permanently on the move—the nomadic peoples of desert, steppe and forest; itinerant groups, as the Vlachs of the Balkan Peninsula whose movements are associated with the practice of transhumance; seasonal workers, as the Italians who seek work in France during the harvest period; daily workers who travel long distances between their place of residence and their place of work. Mobility is

[1] P. H. Karnul, 'The Relations between Male and Female Reproduction Rates', *Population Studies*, vol. 1 (London, 1947), and 'An Analysis of the Sources and Magnitudes of Inconsistencies between Male and Female Net Reproduction Rates in Actual Populations', *ibid.*, vol. 2 (London, 1948–9).

[2] In the *Report of the Royal Commission on Population* (London, 1949), a method of calculating standardized net reproduction rates was devised for this purpose.

a population characteristic no less than age structure, although considerably more difficult to classify and measure.

Because there are so many types of movement of population, only some of which are recorded by national authorities, information about these movements is difficult to compile. These difficulties are discussed at length in various demographic monographs, and it is not intended to do more than summarize a few of the chief ones here, in order to understand the nature of the problems involved in mapping the available statistics.

Comparisons of Vital Statistics and Population Totals. By adding the surplus of births over deaths occurring during a particular decade to the total population of a region at the beginning of the decade, and comparing this sum total with the actual total of enumerated population at the end of the decade, the net migration which has taken place during the period under review may be calculated, by subtracting one total from another. A possible error in the calculation may arise because the vital statistics themselves may not have been recorded accurately and deficiencies in them may lead to the assumption of a higher migration than has actually occurred. Generally, however, the calculation of net migration by this method is sufficiently accurate for most purposes. But this information does not indicate how much immigration and emigration have taken place. The net migration may be nil, although great movements of the population have taken place which counter-balance one another.[1] Net migration data are useful for showing general trends in the movement of population, for example, movement from country to town, or the wider movement from eastern to western Europe which took place during the inter-war years.

Net migration data are available not only on a national basis, but also sometimes for quite small local regions, so that they are of use in determining internal trends in population as well as international and intercontinental movements.

Place of Birth and Place of Residence. This information is largely derived from census returns and may be used to indicate both local and international movements. For example, place-of-birth statistics can be used to illustrate overseas' migration to the United States. They may also be used to show inter-county movements from decade to decade in England. It is not, of course, possible to measure population migration accurately by place-of-birth statistics. They reveal little of the nature of the migrants, nor do they distinguish between permanent and temporary migrants. For example, the Census of 1921 for England and Wales was taken in June when large numbers of people were on

[1] This point is stressed by M. P. Newton and J. R. Jefferey, *Internal Migration: Some Aspects of Population Movements within England and Wales*, General Register Office (London, 1951).

holiday; place-of-birth statistics for Blackpool in 1921 indicate a great migration there which was naturally very temporary. Since place-of-birth statistics are recorded in most cases only when a census is taken, it is impossible to find out the precise date when migration took place.

Another deficiency, in the case of certain British censuses, arises from the divergence between 'civil counties' and 'registration counties', for only occasionally were the two coincident.[1] In the returns of the censuses of England and Wales in 1851 and in 1861, the figures tabulated show how persons born in geographical or civil counties were distributed throughout the registration districts and counties. Apart from these "inconveniences and perplexities" arising out of the complex regional basis of the returns, the place-of-birth statistics provide valuable information on general population movement. They are of great value, particularly to the historical geographer, who has no other data available to provide that perspective so necessary for an understanding of long-term trends in migration.

Records of Passenger Statistics. Another source of information on migration and movement of population is to be found in a variety of records of passenger movements. These records are, for the most part, relatively recent, and they vary immensely in their character, accuracy and completeness from one country to another. Largely owing to the efforts of international organizations, such as the International Labour Office, these records are being brought into uniformity.[2] They include port statistics, frontier-control statistics, data compiled from registration coupons which are issued by home and consular authorities, information based on tickets sold by transport agencies and passport statistics. In some cases, local registration of population movements is customary, and such records are available. These data are naturally of most use in the measurement of international and intercontinental movement of population.

There are numerous difficulties in compiling data relating to internal movements of population. In some countries in Europe, an attempt is made to keep local registers of persons making a permanent change of address involving movement out of a given administrative district.

Daily Movement of Population. In the Census of England and Wales for 1921, the place of work of the enumerated population, as well as place of enumeration, was recorded. The returns were published in a separate volume entitled *Workplaces*, and provide useful data concerning the daily movement of population between work and residence.

Sex and age structure of the population may also be used to reveal information on the movement of populations. If, for example, the balance

[1] For a full discussion, see H. C. Darby, 'The Movement of Population to and from Cambridgeshire between 1851 and 1861', *Geographical Journal*, vol. 101 (London, 1943).

[2] See United Nations, *Problems of Migration Statistics* (New York, 1951).

between the sexes becomes increasingly disproportionate with increasing age, sex-selected migration has probably been taking place, either into or from the region under consideration.

Miscellaneous sources of information about population movement are many. Local passenger services often keep records, road censuses are held from time to time, and the railway companies issue returns of passengers carried. But these miscellaneous statistics are difficult to compile and often only give an incomplete picture of movement at any one time. An interesting source for historical studies of population movement exists in parish marriage registers, which provide a reasonably random selection of movements between parishes about which census returns give no information at all.[1]

Population Growth

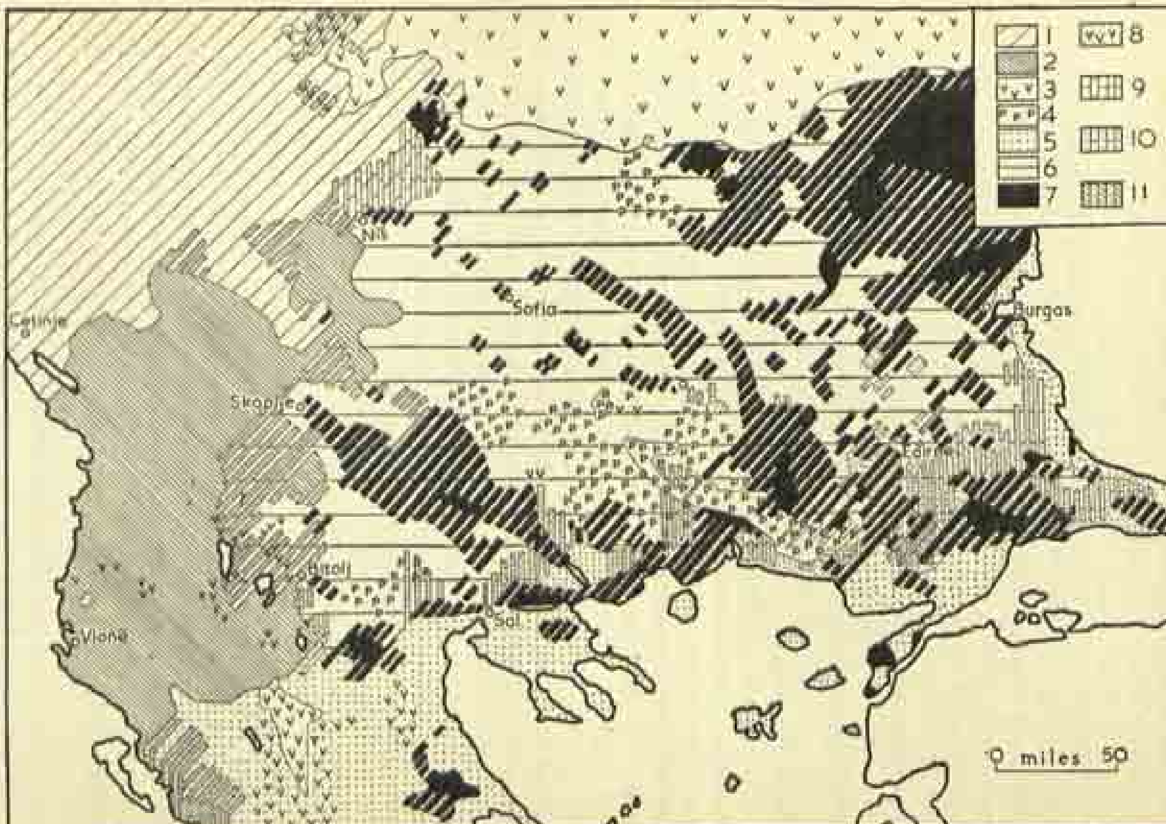
The growth or decline of the population of a region over a certain length of time amounts to the sum of the natural replacement which has taken place plus the net migration into the region during the period under consideration. Regions which enjoy a high natural replacement may experience an actual decline in population because emigration is heavy, and vice versa. The growth of population is often, but not always, related to economic circumstances. Malthus's original theory of the cycle of population growth stated this relationship. The theory has aroused more controversy than any other in the field of demographic studies. The growth of population in any region, whether it is positive or negative, undoubtedly does reflect the history of man's response to the environmental possibilities present in the region. Moreover, future trends in population growth may only be estimated from the evidence provided by the past behaviour of population growth.

The dynamics of population growth vary considerably from one region to another. The growth may take the form of a steady, long-continued increase, it may fluctuate widely from one decade to another, it may exhibit an accelerated or a decelerated rate, it may reach a peak and then decline. Providing that sufficient data are available, and that the boundaries of enumeration units on which the returns are based have not varied too widely from one census to another, the growth and rates of growth of population can be plotted with tolerable accuracy.

Non-Quantitative Maps

Very few population maps are non-quantitative, but certain features of the occupational and ethnic structure of population can be shown

[1] A. Constant, 'The Geographical Background of Inter-Village Population Movements in Northamptonshire and Huntingdonshire, 1754–1943', *Geography*, vol. 33 (London, 1948).



1
2
3
4
5
6
7
8
9
10
11
Cetinje
Niš
Sofia
Burgas
Skoplje
Bitolj
Sal.
Vlonë
0 miles 50

in a non-quantitative manner. Two examples of such techniques of mapping will be considered, with reference to the distribution of ethnic structure.

The Chorochromatic Technique

The most popular type of ethnographic map found, for example, in most atlases, is that which shows territory shaded according to the major ethnic affinity of its population. The popularity of these maps is the result of their application in the field of political geography. Such maps do not usually convey population density, although attempts have been made to overprint distributions on density maps.[1] Nevertheless, they are clear, and the delimitation of ethnic divides is distinctive, indeed much more so than it is in the field. But on such maps admixture of population is difficult to depict, even with the aid of 'interdigitation' (Fig. 129) and even with additional symbols to show the population of towns. Moreover, these maps generally over-simplify distributions; huge areas may be shaded to represent an ethnic group with a population of less than one person per square kilometre, while densely-populated districts shaded to represent another group may be so small as to escape notice. It is also particularly difficult for the eye to give equal weight to different types of shading, especially if colour is used; red always gives an impression of a more intensive distribution than would be the case if purple or yellow were used.

Inscriptions

In the earliest ethnographic maps, such as that shown in Fig. 130, the problem of showing distributions was solved in a crude but effective manner. The names of the ethnic groups were inscribed over the territory with which they were associated; majority populations were shown by capital letters and minorities by lower-case. This method is still

[1] A. Haberlandt, 'Karte der Völker Europas nach Sprache und Volksdichte' 1:3,000,000 (Vienna, 1927).

FIG. 129. A CHOROCHROMATIC MAP OF ETHNOGRAPHIC DISTRIBUTIONS

Based on H. R. Wilkinson, *Maps and Politics: A Review of the Ethnographic Cartography of Macedonia* (Liverpool, 1951).

The map shows the distribution of ethnic groups in the Balkan Peninsula according to a map compiled by K. Sax in 1878.

The references in the key are as follows: **1.** Serbo-Croats; **2.** Albanians; **3.** Rumanians; **4.** Pomaks; **5.** Greeks; **6.** Exarch Bulgarians; **7.** Circassians, Tartars, Turks and Turcomans; **8.** Graeco-Vlachs; **9.** Serbo-Bulgarians; **10.** Graeco-Bulgarians; **11.** Graeco-Albanians.

Note the use of 'interdigitations' to show both admixture of ethnic groups and transitional types. The original map was in colour but by choosing distinctive shading it has been interpreted in black and white.

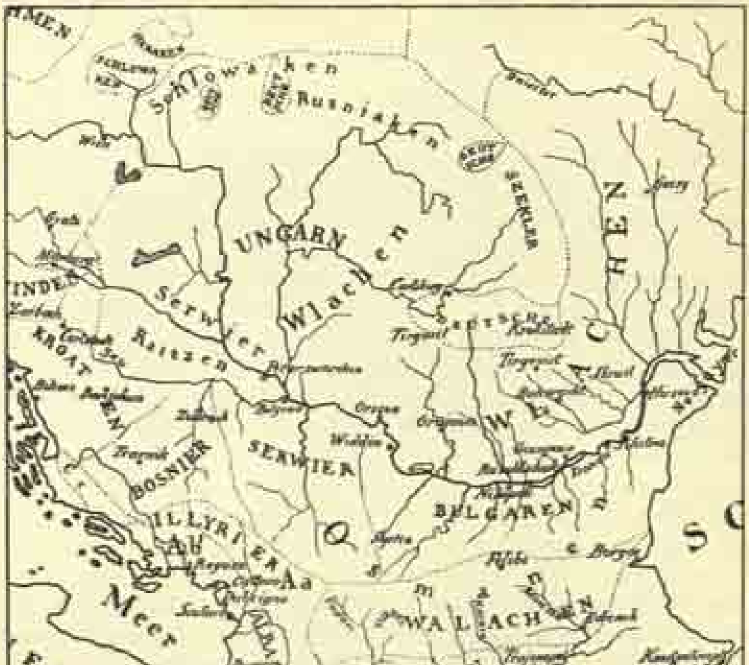


FIG. 130. AN INSCRIBED MAP OF ETHNOGRAPHIC DISTRIBUTIONS

Based on H. R. Wilkinson (*op. cit.*).

This is part of F. A. O'Etzel's map showing the distribution of the peoples of Europe, published in 1821. Ethnic groups having a relative majority are indicated by capital letters and minorities by lower case.

in use to-day, for example, to show tribal distributions in African territories. It does not convey density of population, although the names may be inscribed over population density maps, nor does it give a sufficiently accurate impression of complex ethnic structure when an inter-mixture of groups has to be plotted. It does not allow comparative strengths of the component groups to be portrayed, and it fails to convey any accurate impression of the limits of specific groups.

Choropleth Maps

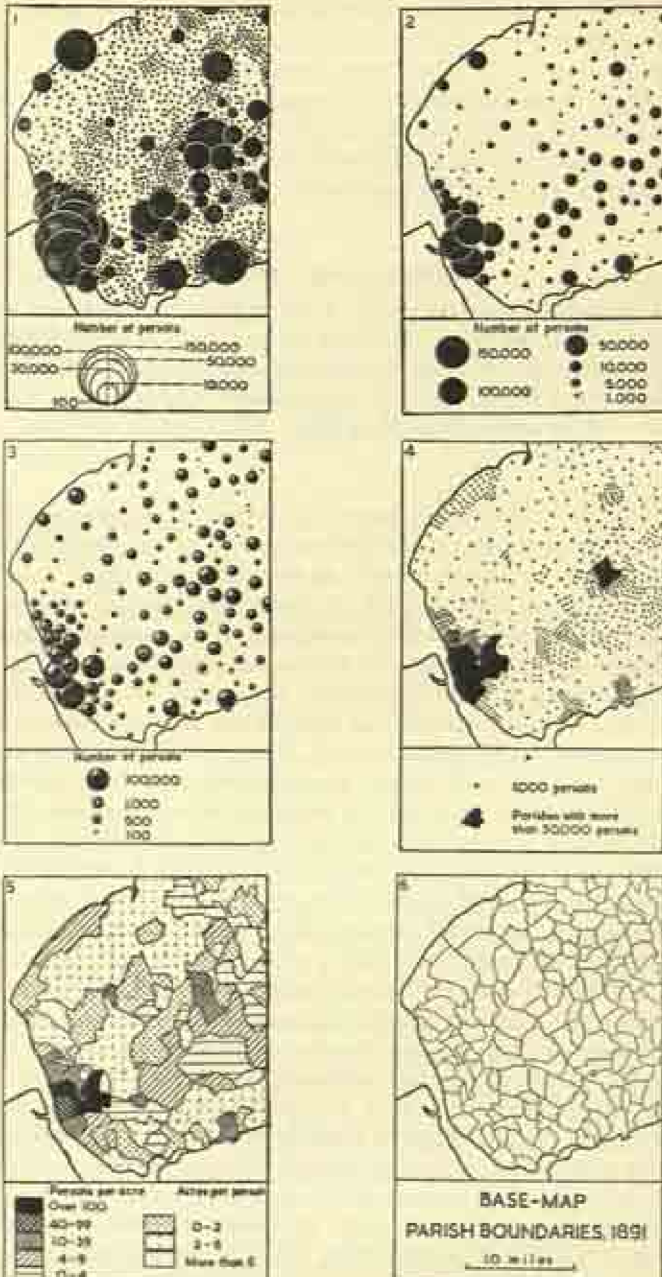
If the isopleth is the chief tool of the climatologist, the choropleth may be said to be the chief tool of the human geographer in his quantitative treatment of the distributional aspects of population. Therefore choropleth maps receive priority of treatment in this section, and they are dealt with in more detail than other quantitative methods.

Population Density

To create an accurate impression of density, it is necessary to consider the areas of enumeration districts as well as the totals of population. Density is usually expressed as the ratio of a given number of persons to a given area of land, as twenty persons per square mile. It may for certain purposes be represented as the ratio of a given area to a given number of persons, as four acres to one person (Fig. 135).

The problem of constructing density maps may be clarified by considering, as a specific example, the distribution of population in Southwest Lancashire in 1891 (Figs. 131–6), based on the Census of England and Wales for that year. Areas present something of a problem in that returns of parish areas are not accurate in early censuses, because detailed cadastral survey was often lacking; frequent changes of parish boundaries give rise to anomalies between recorded and actual areas of parishes; and coastal-parish acreages often included areas of sea and foreshore. By a careful scrutiny of the census acreages and a comparison with base-map data, major errors in the calculation of the density of population in each parish may be avoided. Since the census returns give the totals of population and acreage for each parish, it was necessary to reduce these figures to persons per square mile in each parish, and a nomograph was used (see p. 32).

When the densities had been calculated, it became obvious that because only a limited range of shading was practicable, only certain categories of population density could be shown on the map. As they were to be divided into some half-dozen categories, care had to be exercised in the selection in order to ensure that the major density values were given full weight (Fig. 135). A dispersion diagram was helpful in ensuring that important variations in density were not


1
Number of persons
100,000
150,000
50,000
30,000
10,000
100
2
Number of persons
150,000
50,000
10,000
5,000
1,000
100,000
3
Number of persons
100,000
1,000
500
100
4
1000 persons
Parishes with more than 50,000 persons
5
Persons per acre
Acres per person
Over 100
40–99
10–39
0–2
2–6
More than 6
6
BASE-MAP
PARISH BOUNDARIES, 1891
10 miles

overlooked. It should be noted that certain aspects of the distributions of population are better illustrated by expressing regional differences in terms of deviations from average national density. This method does not altogether solve the problem presented by great ranges of density, but it has a special value in the portrayal of population concentrations.[1]

Line-shading or colour-wash are the most effective methods of depicting the densities once they have been decided; the problem of shading is discussed above (p. 34). In the case of population distributions, the conventional impression of increasing density conveyed by the graduation from white to black is so firmly established that there is little to be gained by using colour (Fig. 138).

The Dasymetric Technique. It may so happen that the data for any given region may not be sufficiently complete to give a detailed picture of the variations in density from one place to another, as is the case when the returns are made for very large administrative divisions only. In this case, it may be necessary occasionally to ascertain details of distribution on the map which are not actually given in the returns.[2] Or, even if returns are made on a parish basis, it may be desirable for certain purposes "to emancipate ourselves from undue restraint of administrative boundaries [. . .] and so avoid the bizarre sort of tartan pattern frequent in population distribution maps [. . .]".[3] For such work it is necessary first, to consult topographical and land-utilization maps of the region under consideration, and then to pick out from these maps districts such as moorland, marsh, heath, etc., on which no settlement occurs, and second, to delimit settlement zones as denoted by the settlement patterns. These zones have to be superimposed upon the base-map. Their areas must also be calculated. Suppose, for example, that for each administrative division the information available were as follows:

[1] See A. Hoffman, 'India: Main Population Concentrations', *Geographical Journal*, vol. 111 (London, 1948).

[2] J. K. Wright, 'A Method of Mapping Densities of Population with Cape Cod as an Example', *Geographical Review*, vol. 26 (New York, 1936).

[3] A. Stevens, p. 49, *op. cit.*

FIGS. 131–6. CONTRASTING TECHNIQUES OF SHOWING POPULATION DISTRIBUTIONS

Source of data: *Census of England and Wales, 1891*, vol. 1 (London, 1893).

The maps show the distribution of population in south-western Lancashire only. In **1** dots and proportional circles are employed; in **2** proportional circles only are employed and the form of key and proportional scale have been changed; in **3** proportional spheres are employed; **4** is a modified dot map; and **5** is a simple choropleth map. The data used for each map are identical.

	Population	*Total Area*
Districts without settlement .	Unknown	80 sq. km.
Intermediate districts . .	Unknown	60 sq. km.
Closely-settled districts . .	Unknown	10 sq. km.
Administrative division . .	60,000	150 sq. km.

The mean density of population for the whole unit is 400 persons per square kilometre. If, however, the districts without settlements are regarded as unpopulated, then the intermediate and closely-settled districts may be assumed to have a population density of:

$$\frac{60{,}000}{60+10}=857 \textit{ persons per sq. km.}$$

These new density values, 0 and 857 respectively, will give a reasonably accurate and more detailed picture of distribution of population then the one uniform density of 400. The calculation may be carried a stage further and reasoned guesses made of the population densities for the intermediate and closely-settled districts.

A. Geddes used these methods in his analysis of the population of Bengal,[1] in his case not because data for smaller units of enumeration were not available, but because the labour involved in utilizing them would have been enormous. He was also concerned with showing the 'geographical' distribution of population in relation to land utilization rather than in relation to administrative boundaries. Hence he correlated statistical and topographical data to produce densities of population for different categories of land, such as forest and cultivated land. His final densities were directly related to the 'unit area of daily life' of the persons making up the population. The formula used for obtaining these densities is worth noting. If for an administrative unit of area A the population returned by the census is P, the statistical density is P/A. If the population is to be redistributed between forest and cultivated land, then a reasoned guess must be made of the number of forest dwellers (P_1) and the area of forest calculated from land-utilization maps (A_1). The remaining population living in the cultivated lands will then be $P-P_1$, and the area of cultivated land $A-A_1$. The density of population in the cultivated land will be:

$$\frac{(P-P_1)}{(A-A_1)}$$

This method has many applications, for example, it might be applied

[1] A. Geddes, 'The Population of Bengal, its Distribution and Changes: A Contribution to Geographical Method', *Geographical Journal*, vol. 89 (London, 1937).

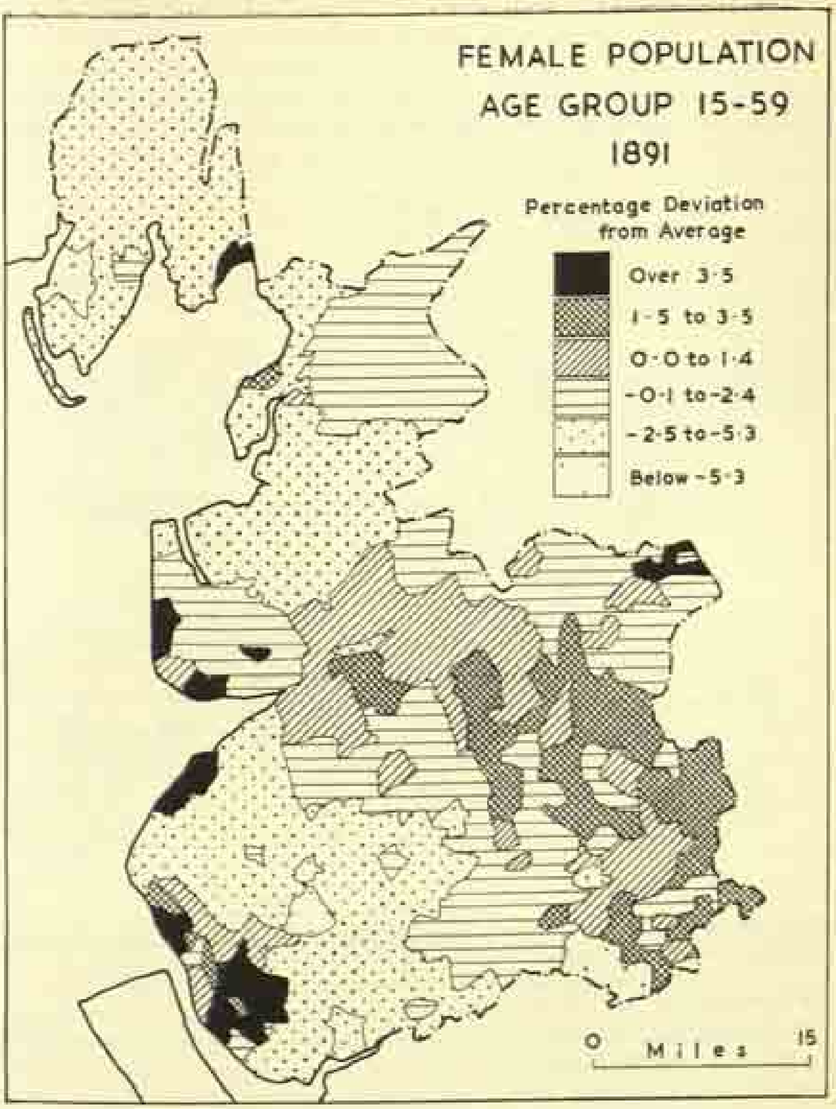


FIG. 137. A DEVIATIONAL CHOROPLETH MAP

Source of data: *Census of England and Wales, 1881*, vol. 3 (London, 1883).

The map is intended to reveal regional variations in the age structure of the female population in Lancashire aged over 15 and under 60. By showing deviations from the national average, the variations are given sufficient emphasis to stand out clearly.

The map was compiled on the basis of administrative divisions.

to the distribution of population as between moorland and vale, or between built-up areas of towns and scattered rural settlement.[1]

The dasymetric technique can also be applied to the mapping of indices of 'comparative density' (see p. 225), by the choropleth method, where it is desired to show population pressure in terms of availability

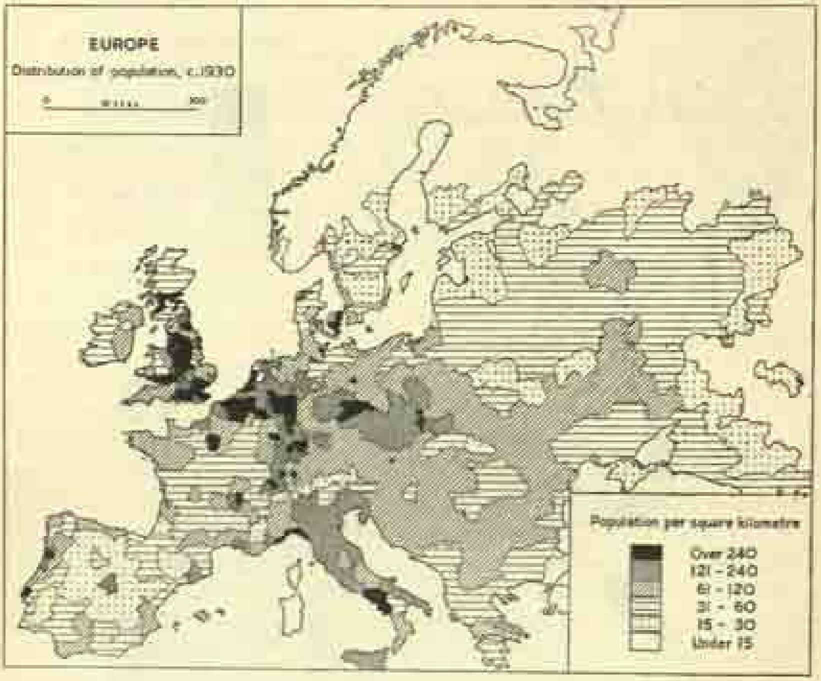


FIG. 138

Data and base-map from D. Kirk, *Europe's Population in the Inter-war Years* (Geneva, 1946).

of agricultural land. Referring to maps of this type, A. Stevens points out that in Scotland the head-dyke might be used to limit "the 'field' of pressure on the land".[2]

Sex and Age Distribution

A series of choropleth maps can be used to show the detailed distribution of population by ages. Anomalies are more effectively illus-

[1] See *Great Britain, Population Density, 1931*, compiled by the Ministry of Town and Country Planning, sheet 2, 1:625,000 (Ordnance Survey, Southampton, 1944).

[2] A. Stevens, p. 51, *op. cit.*

trated if the percentages of persons in each group is plotted and not the absolute totals. Regional deviations from the national norm may also be plotted with effect (Fig. 137). The regional deviations are obtained by noting the difference between local age-group percentages and national age-group percentages. A cartographical analysis of population structure along these lines has many uses. It affords

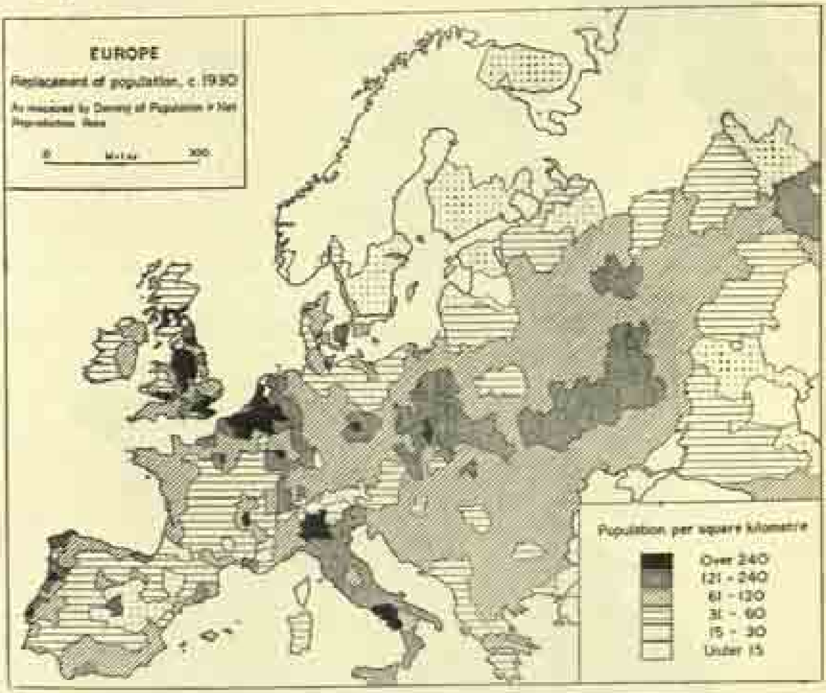


FIG. 139

Data and base-map from D. Kirk (*op. cit.*).

Figs. 138–9 are intended to be comparative maps; whereas one shows the distribution of population, the other gives some indication of the trend of distribution.

information about the availability of male and female labour in different localities; it is of help in the interpretation of differential fertility rates and trends; it gives many clues about long-term migration. Maps of this type are indispensable to planners in economic and social spheres.[1]

Ethnic and Occupational Structure

The choropleth technique is not eminently suited to depict complex

[1] The economic significance of age differences in the population has been analysed in A. Sauvy, *Richesse et Population* (Paris, 1943).

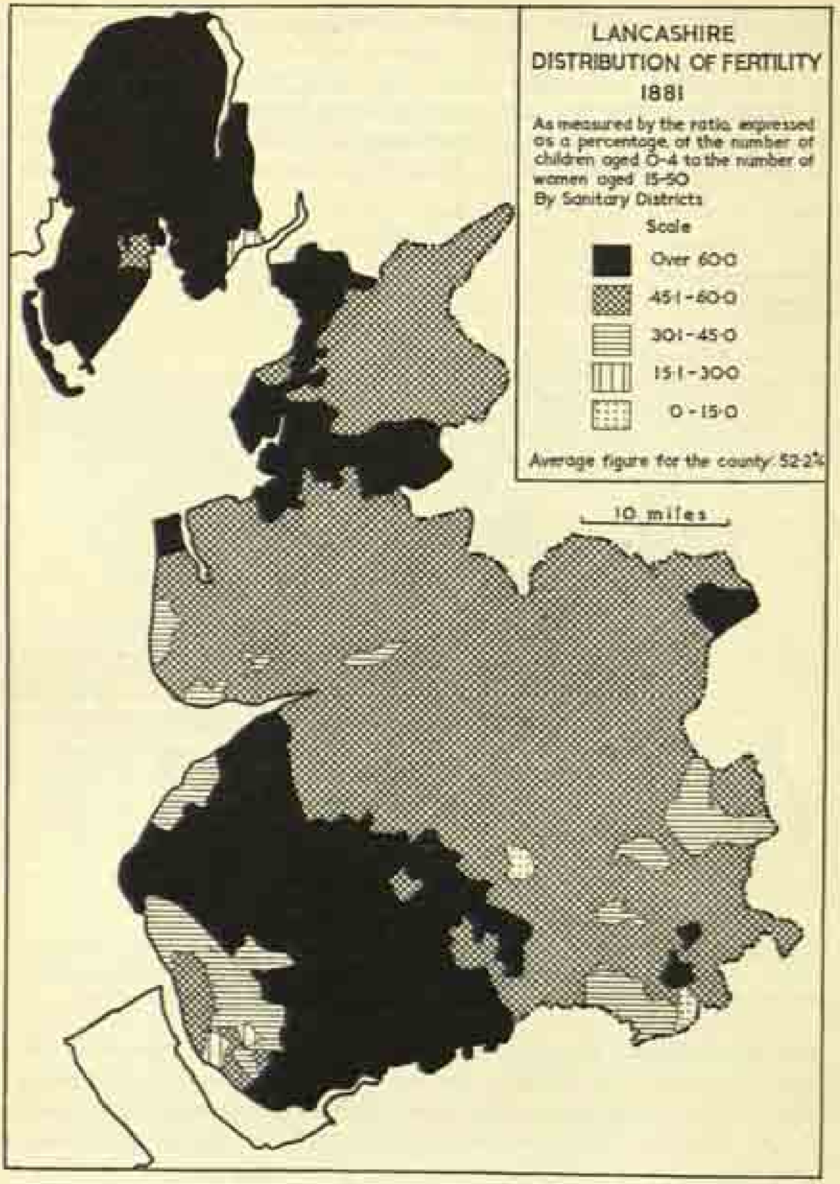


FIG. 140

Source of data: *Census of England and Wales, 1881*, vol. 3 (London, 1883).

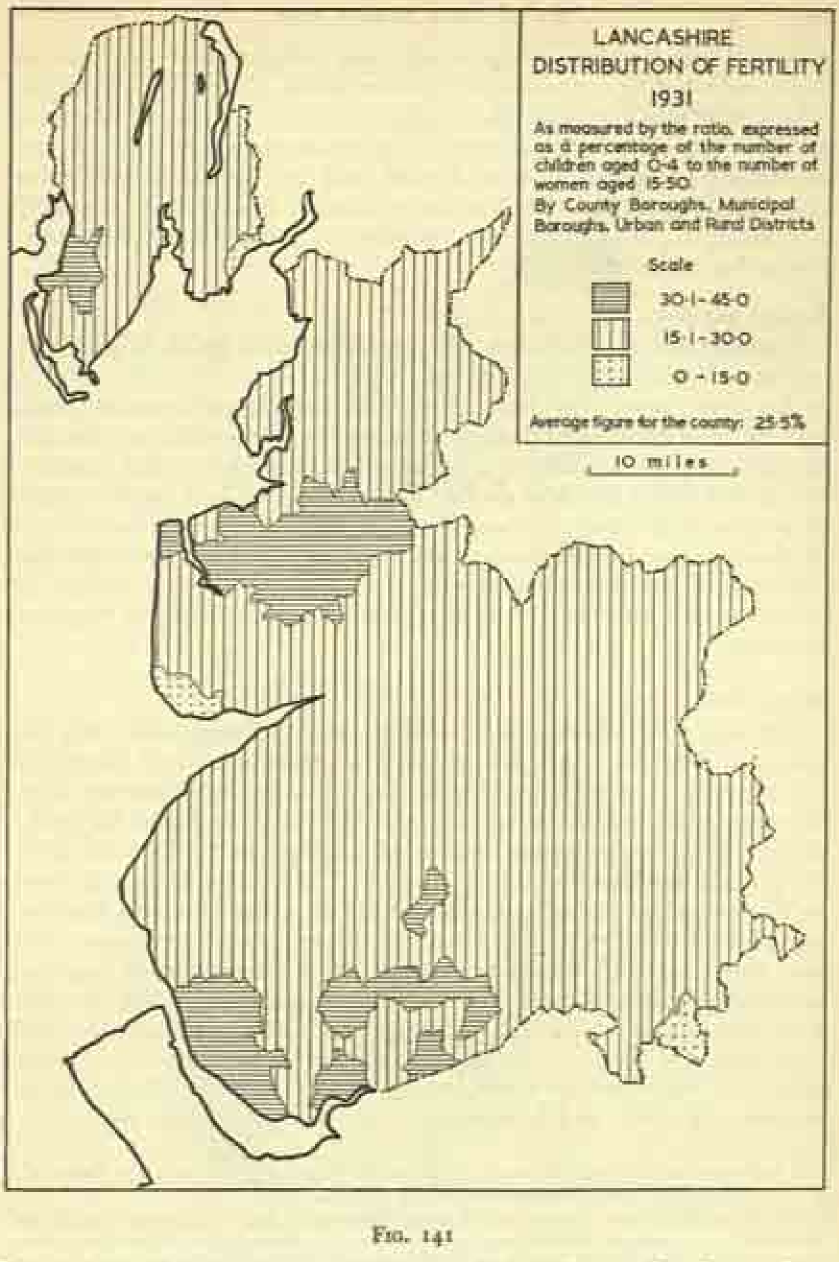


Fig. 141

Source of data: *Census of England and Wales, 1931, County of Lancaster* (London, 1934).
Figs. 140–1 have been compiled on the basis of identical density scales for the purpose of comparison.

distributional features of the ethnic and occupational structure of population but in certain cases it proves useful. If two elements in the ethnic structure are to be plotted, for example, Czechs and Germans in Bohemia, a proportional scale of values to show the ratio of one nationality to another can be devised and the distribution of ratios shown by choropleths.[1] To show more than two elements, for example, a number of nationalities, or a number of industrial employments, colour has to be employed.[2]

Replacement Rates

Replacement of population, whether indicated in terms of gross and net reproduction rates (Figs. 138–9), or by fertility ratios (Figs. 140–1), or by crude birth (Fig. 142), death and natural replacement rates, may be most conveniently mapped by means of choropleths. Changes in replacement rates may also be effectively mapped in this manner, but in this case a problem occurs; to show positive and negative rates or positive and negative changes, it is necessary to use special systems of shading (see p. 36). Dudley Kirk (*op. cit.*), in his map of the distribution of net reproduction rates in Europe, used two colours to overcome this difficulty, black to represent positive and red negative qualities.

Migrations

Out-migration, in-migration and balance of migration may be shown by means of choropleth maps. The methods are best illustrated by reference to a specific example, in this case out-migration from Worcestershire in 1861 (Figs. 143–6). The data are based on birthplaces given in the census returns of England and Wales for 1861 for over six hundred registration districts. The number of persons born in Worcestershire and enumerated outside the county for each registration district was first of all calculated. These totals were mapped in four ways; (*a*) each total was expressed as a percentage of the total number of migrants from Worcestershire up to that year; (*b*) each total was related to the area of its particular registration district and expressed as a density in terms of persons per 10,000 acres ; (*c*) each total was expressed as a percentage of the total population in its enumeration area; and (*d*) absolute totals were considered *per se*.

[1] A pioneer of this method was E. Hochreiter, 'Nationalitätenkarte von Böhmen', 1: 1,850,000, *Petermann's Mitteilungen*, vol. 29 (Gotha, 1883).

[2] This method was adopted in '*Langues Maternelles dans le Royaume S.H.S. par Communes*', 1: 1,500,000, Publié par la Direction de la Statistique d'Etat (Sarajevo, 1924), which showed the distribution of languages in Jugoslavia according to the Census of 1921. See also B. V. Semenow—Tian—Schanský, 'Handel und Industrie im Europäische Russland', 1: 750,090, *Petermann's Mitteilungen*, vol. 59 (Gotha, 1913), in which 8 occupational groupings are shown according to the percentage of persons employed (0–20%, 20–50% and over 50%).

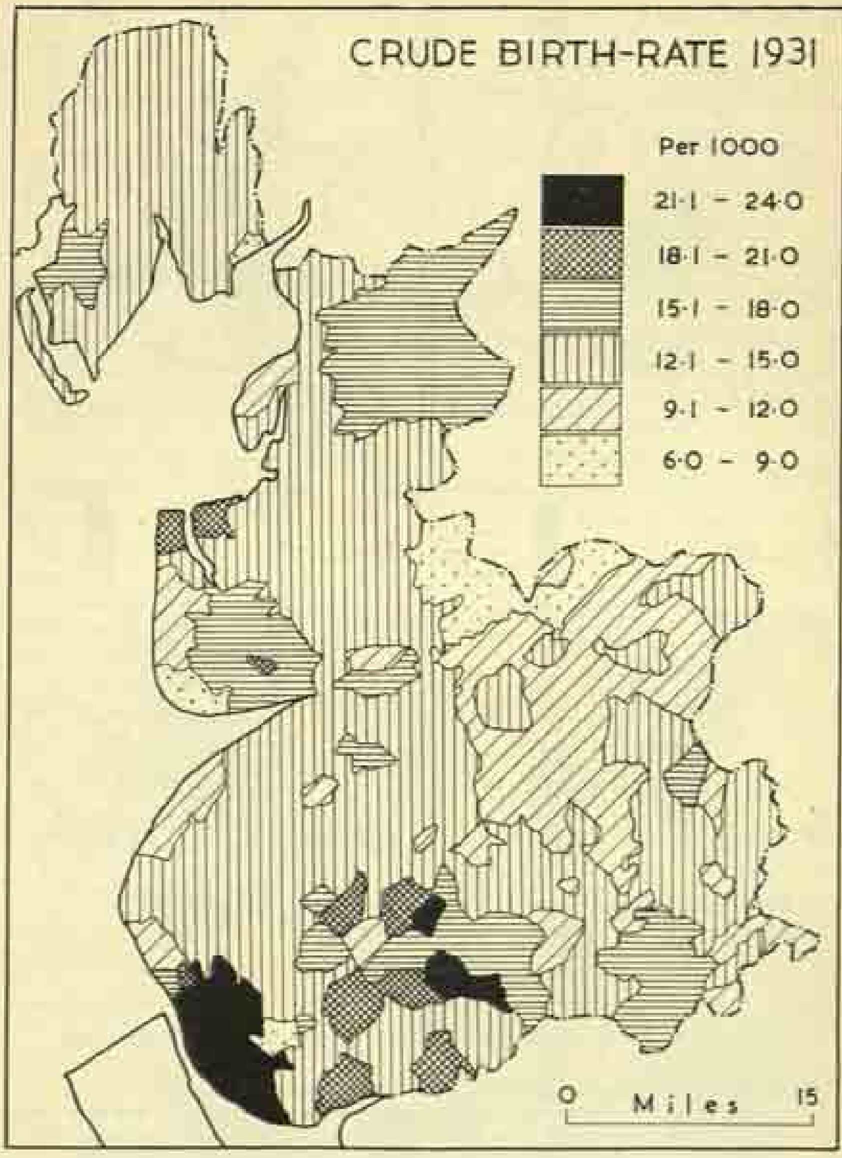
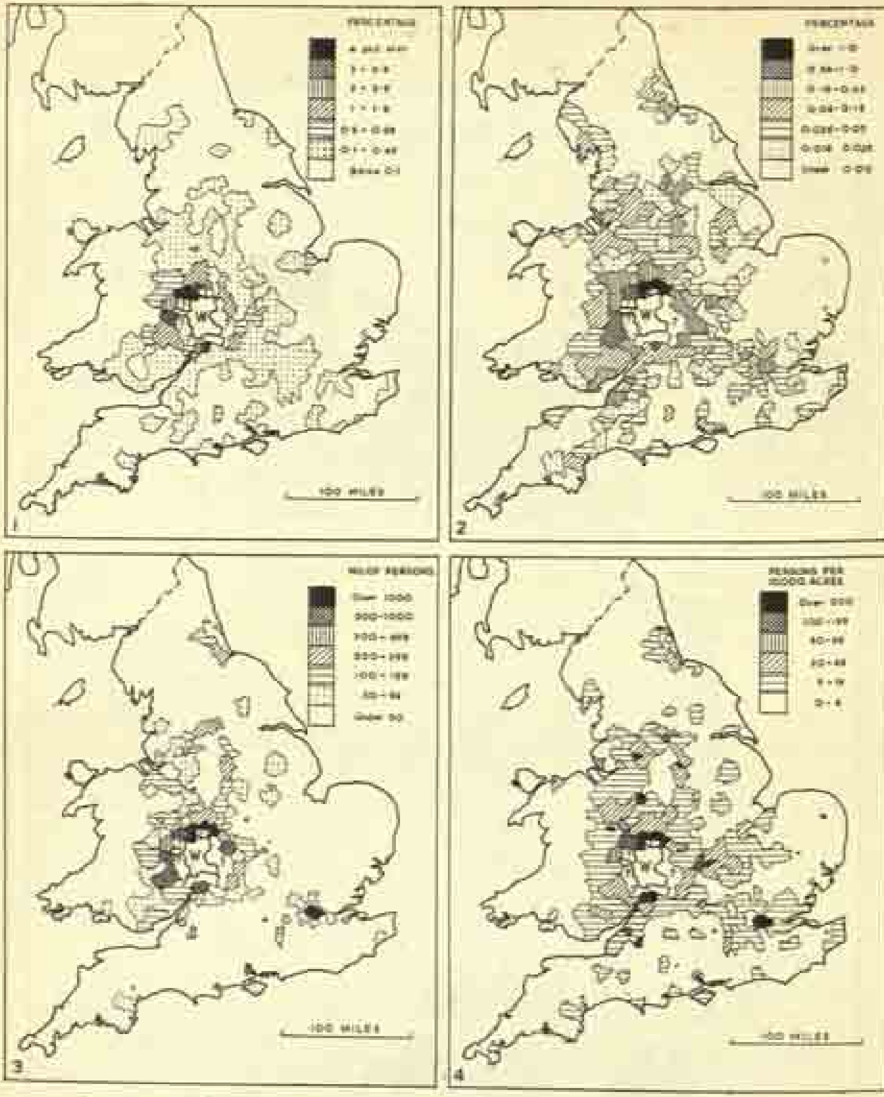


FIG. 142. A CHOROPLETH MAP OF VITAL STATISTICS

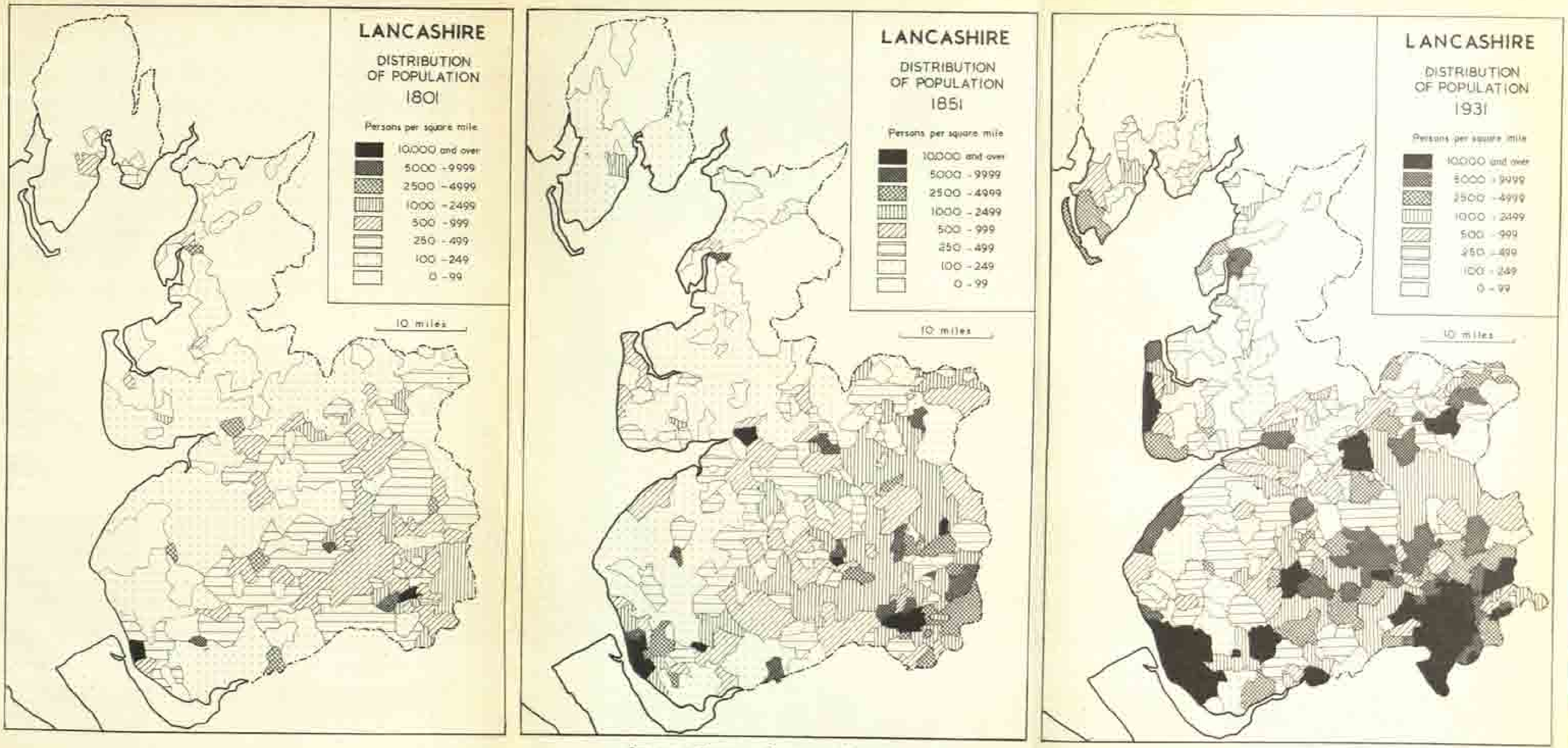
Source of data: *The Registrar-General's Statistical Review of England and Wales for the Year 1931*, Tables, pt. 2, Civil (London, 1933).
The distribution is by administrative divisions.



FIGS. 143–6. FOUR METHODS OF MAPPING MIGRATION BY CHOROPLETHS

Source of data: *Census of England and Wales, 1861*, vol. 2 (London, 1863).

The number of natives of Worcestershire living outside the county in 1861 has been mapped to give an indication of migrants from Worcestershire on the basis of registration districts. **1** shows migrants from Worcestershire expressed as a percentage of the population of each registration district into which they have moved; **2** shows migrants for each registration district expressed as a percentage of the total number of emigrants from Worcestershire; **3** simply shows registration districts shaded to show the absolute number of migrants they each received; and **4** shows the number of migrants from Worcestershire in each registration district expressed in terms of number per unit of area. No separate data were available for the Isle of Man, and Scotland has been excluded.



Figs. 147–9. Population Distribution Maps in Series

Source of data: *Census of England and Wales* (various dates).

Growth of Population

Probably the most obvious method of showing population growth is to prepare a series of maps in chronological order showing the past and present distributions. Figs. 147–9 incorporate a series of such maps for Lancashire between 1801 and 1931. Such a series gives a broad picture, but it is a difficult task to measure and compare the growth of population from one district to another without recourse to a very close examination of the map.

Intercensal Changes in Population. To overcome this difficulty, intercensal changes in population can be shown directly, usually in the form of the percentage change in the increase or decrease of population which has occurred between two censuses. These changes are best plotted in the form of a choropleth map (Fig. 150). Some further indication of absolute numerical changes may be given by superimposing proportional symbols on the choropleths.[1]

There are three main difficulties in the preparation of choropleth maps of this nature. In the first place, the dates of the two censuses have to be chosen with care. For example, if the years 1801 and 1931 were chosen for Ireland, these would give no indication of the real nature of the growth and decline of Irish population in the interim decades. In the second place, the map must be based on the enumeration units given in the latest census to be used. Almost certainly changes of unit boundaries will have taken place between the two censuses, and amalgamation or partition of various units will also obscure the issue. In some parts of Britain, for example, in the Manchester and London areas, it is a most formidable task to equate the regional bases of the returns between a census of the early nineteenth century and another of more recent date. Intricate research into changes in the boundaries of parishes, wards and boroughs is a necessary prelude to the preparation of the base-map. Since many changes are not even recorded, this task involves laborious comparisons of acreages. The third problem is one of presentation. Almost invariably some parishes will have declined in population, others will have gained. A two-fold division of shading is therefore necessary to distinguish between each category; this problem has been discussed in chapter I (see p. 36). A simple solution is offered in Fig. 150.

Intercensal changes may be plotted also by means of indices showing the rate of change as compared with the corresponding national rate. An index of the national change is arrived at by dividing the national total of population for, say, 1931, by that for 1831, if these two censuses are being considered. In the example given below:

[1] See *Great Britain, Population. Total Changes, 1931–39*, compiled by the Ministry of Town and Country Planning, sheet 2, 1:625,000 (Ordnance Survey, Southampton, 1429.)

$$\textit{Index of Change} = \frac{\textit{National total, 1931}}{\textit{National total, 1831}} = \frac{5{,}000{,}000}{2{,}000{,}000} = 2 \cdot 5$$

Local indices are similarly calculated, and then plotted using the choropleth method. Some distinction should be made between parishes with an index of less than 2·5, i.e. below the national rate of growth, and those above that figure.

FIG. 150. GROWTH CATEGORIES IN BELGIUM

Based on a map in H. M. Kendall, 'A Survey of Population Changes in Belgium', *Annals of the Association of American Geographers*, vol. 28, p. 152 (Lancaster, Pa., 1938).

Population Peaks. Line-graphs may show the behaviour of the growth of population for individual localities fairly well, but they are hard to use when hundreds of localities are under consideration. To analyse geographically the evidence provided by the graphs some of the essential features have to be transferred to maps. For example, the dates at which population peaks are attained are easily plotted on a map.[1]

[1] S. D. Dodge, 'A Study of Population Regions in New England on a New Basis', *Annals of the Association of American Geographers*, vol. 25 (Lancaster, Pa., 1935).

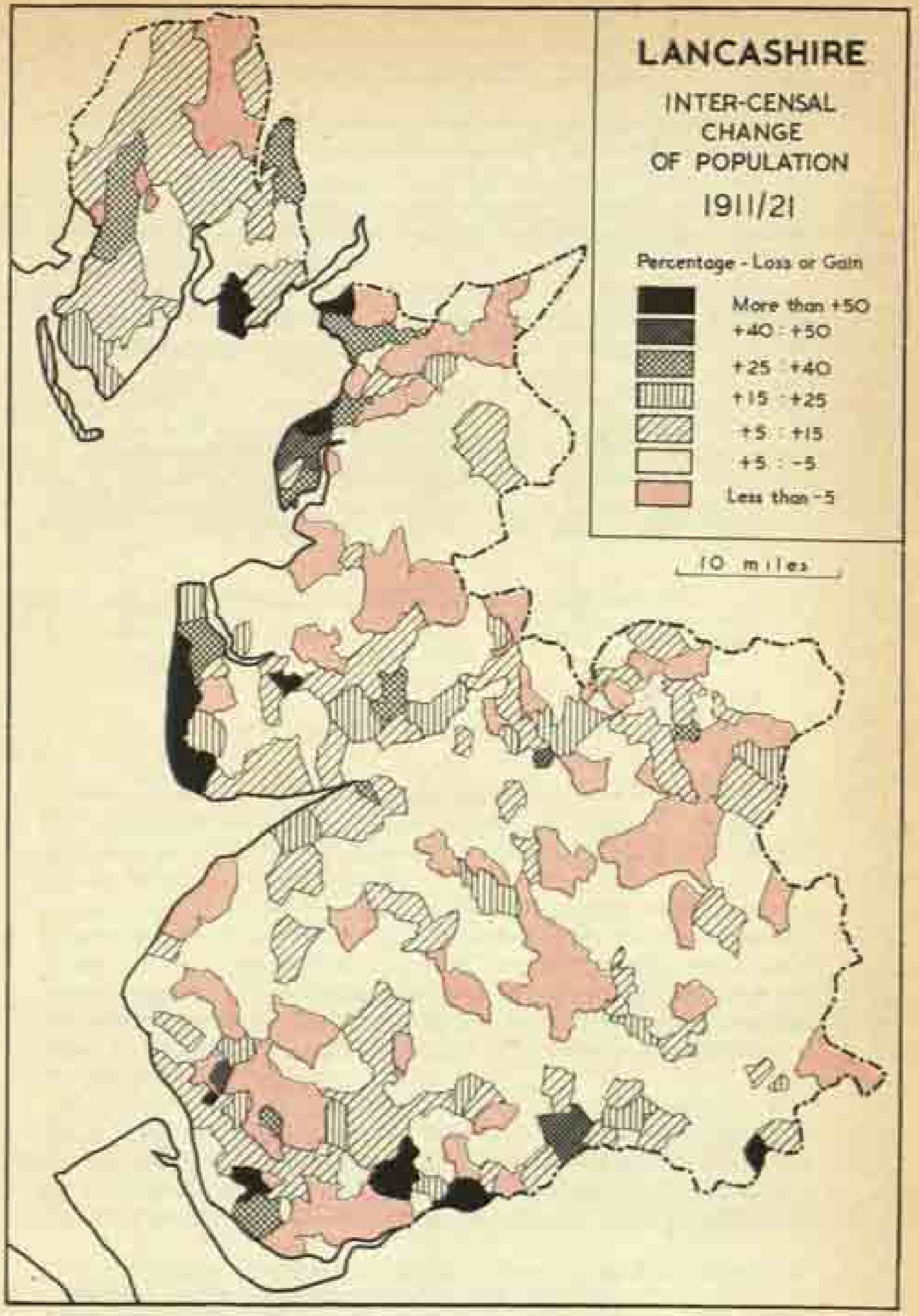


FIG. 151. A CHOROPLETH MAP OF INTERCENSAL POPULATION CHANGE

Source of data: *Census of England and Wales* (various dates).

The map is based on returns enumerated on a parish basis and areas with an absolute population decline of over 5 per cent have been tinted red.

The distribution of the dates of peaks of population plotted in this manner indicates those regions the population of which is in decline; the earlier the peak, the longer the period of decline. When contiguous districts have roughly the same dates of peak population, some underlying regional economic cause, such as mineral exploitation, may be judged to be responsible.

Growth Categories. It is possible to show the distribution of peak populations according to the time when they occurred. S. D. Dodge distinguished four categories of population trend based on a careful

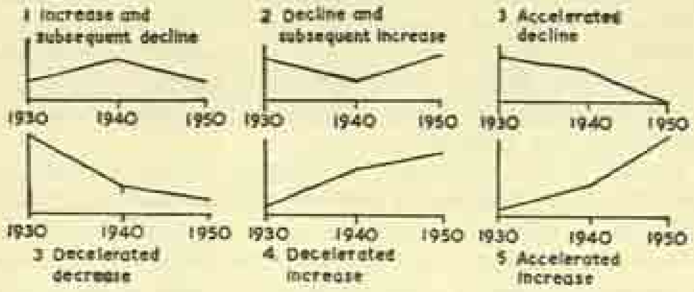


FIG. 152. KOHN'S GROWTH CATEGORIES

analysis of patterns of growth of population for parts of New England. The categories were (*a*) continued growth, (*b*) decline of 25 per cent from a peak, (*c*) decline of 25–50 per cent from a peak, and (*d*) decline of over 50 per cent from a peak.

These categories may, of course, be expanded to include various degrees of irregularity in growth and decline. They may be effectively illustrated by the choropleth technique, in which case they reveal long-term changes in the population balance of various regions. They are particularly useful in illustrating relative declines of populations (Fig. 151). H. M. Kendall used this method of analysis in his treatment of the population of Belgium.[1]

Other types of growth categories can be used. For example, G. F. Kohn in his work on population trends in the United States employed the six categories given in Fig. 152.[2] These categories are best shown by a series of maps, but they may be incorporated in one map with the aid of an ungraded shading system (see pp. 36-7). Other population-

[1] H. M. Kendall, 'A Survey of Population Changes in Belgium', *Annals of the Association of American Geographers*, vol. 28 (Lancaster, Pa., 1938).

[2] G. F. Kohn, 'Population Trends in the United States since 1940', *Geographical Review*, vol. 25 (New York, 1945).

growth categories may be distinguished upon inspection of the data relating to the growth of particular populations.[1]

Variability. In a paper on population trends in India, A. Geddes demonstrated that variability in the growth of population has a distinctive regional significance.[2] The normal type of intercensal population-growth map does not show variability. Two enumeration districts, for example, might exhibit similar percentage growths of population, but whereas one may have had a steady increase of population, the other may have experienced all kinds of population vicissitudes. The census dates are purely arbitrary and may tend to cloak any variability in the population growth (Fig. 153, top). Geddes showed distribution of variability by means of a variability index. This was calculated by comparing the actual curves of growth of population, in the case of each enumeration district, with a theoretical normal curve of growth; the mean percentage deviation between the two curves was taken as an index (Fig. 153, bottom).

In practice it is not necessary to calculate a hypothetical curve of growth. A straight line drawn between the two intercensal plottings will provide a sufficiently accurate curve for the measurement of variations. Alternatively, a curve may be sketched by reference to the national figures. If 1801 and 1921 are taken as the intercensal dates, an index of population variability may be calculated in the following way. Superimpose the percentage growth of population, decade by decade, for the enumeration district under consideration, upon the hypothetical curve of growth represented by a straight line drawn between the plottings for 1801 and 1921. The two curves will deviate from one another at as many as ten points. These deviations may be measured in terms of percentages by reference to the scale used on the graph. All ten variations should be added, and

[1] See, for example, 'Carte dynamique de la région parisienne', in A. Demangeon, 'France Economique et Humaine', part 2, *Géographie Universelle*, vol. 6 (Paris, 1948).

[2] A. Geddes, 'The Population of India. Variability of Change as a Regional Demographic Index', *Geographical Review*, vol. 32 (New York, 1942).

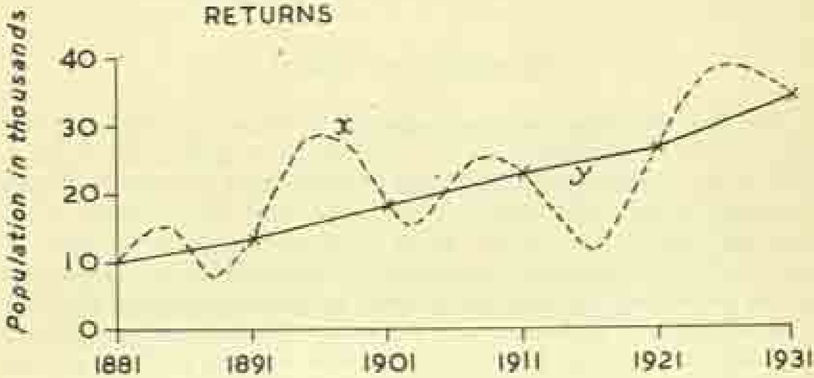
FIG. 153

In the top diagram, the pecked line (x) indicates the true curve of the growth of population and the solid line (y) the curve as adjudged by reference to census returns.

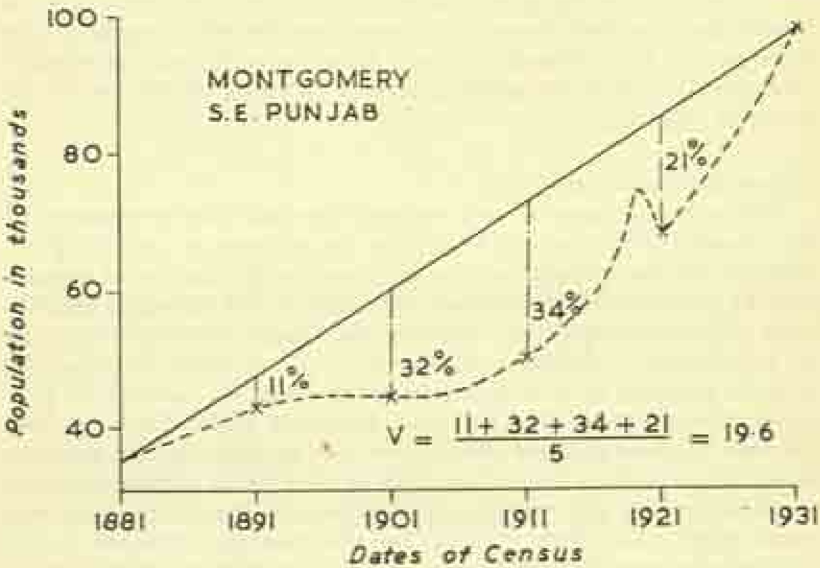
The bottom diagram is based largely on A. Geddes, 'The Population of India', *Geographical Review*, vol. 32, p. 569 (New York, 1942).

The pecked line shows the population curve sketched from census returns and from known dates of crises. The solid line represents the theoretical curve of growth. The two curves are known to deviate at four points, each marked by a cross. The amounts of deviation are calculated on a percentage basis and the variability coefficient (V) found by Geddes' formula.

1. A HYPOTHETICAL CASE OF HOW VARIABILITY IN POPULATION GROWTH MAY BE CONCEALED IN CENSUS RETURNS



2. MEASUREMENT OF VARIABILITY INDEX



the mean percentage deviation found by dividing by eleven; the variability index so obtained can be plotted conventionally by means of a choropleth map. A. Geddes found, for example, that a range of six variability indices was practicable in the case of India.

Quantitative Symbols

Dots

The dot technique may be employed to show the absolute total distribution of population or the distribution of individual elements within the population, such as Poles in Belgium or France. Technical problems in the construction of dot maps have been referred to in chapter I (see p. 19). In the case of population maps, if the value of each dot is too big sparsely-populated districts will not be represented at all, if too small the dots will coalesce in densely-populated districts. The stratagem of dispensing with dots altogether in densely-populated parishes and shading them black has been adopted in Fig. 135, but this is hardly a true solution of the problem.

As a general rule, the dots have to be distributed evenly within the boundaries of the area of the population which they represent, but it is possible in the case of dots of small value to place them according to the distribution of dwellings. This involves, of course, the consultation of topographical maps and plans. Dot maps of town populations are often shown in this way, one dot with a value of 5 or more persons being placed over each house or each group of houses.[1] Occasionally it may be useful to employ two sizes of dot for special purposes (Fig. 154).

Proportional Squares and Circles

The total population of each enumeration unit may be represented by a symbol of proportional size, either by a square or a circle. These symbols are particularly suitable for showing distribution of population by countries to demonstrate the political and economic significance of varying population resources. Rectangles proportional in size to populations of different regions, countries or states, for example, may be grouped in their approximate geographical position for purposes of comparison of populations and land areas. They can also be used to show detailed distribution, but in this case the problem arises of choosing a scale of symbols so that small populations may be distinguished, and yet large populations not obscure neighbouring small populations (Figs. 132–3). The disadvantages attached to this method are first, that the extreme range of population density to be

[1] See such maps in W. William-Olsen, 'Stockholm', *Geographical Review*, vol. 30 (New York, 1940).

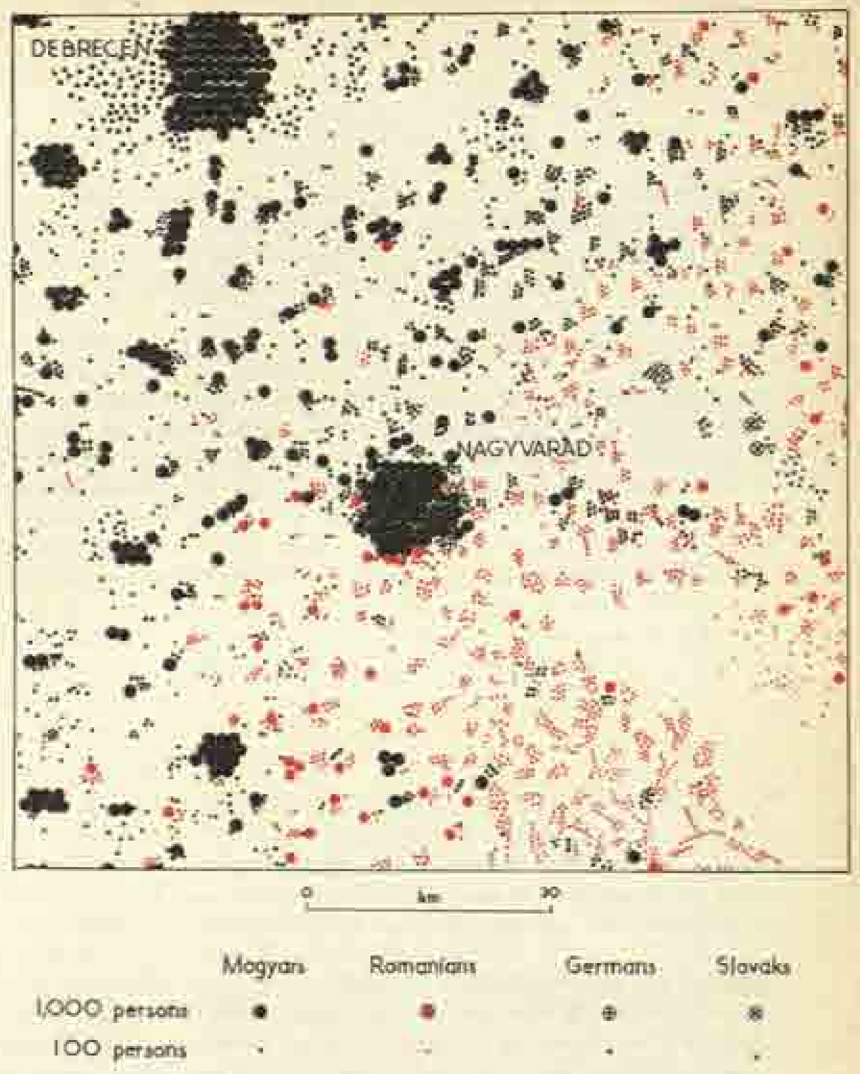


Fig. 154. Ethnographic Distributions by Dots of Two Sizes

Based on Z. S. Bátky *et al. Magyarország néprajzi térképe település és lélekszám szerint*, 1:300,000 (Budapest, 1919). Data from Austro-Hungarian Census of 1910.

In common with Figs. 155-7, this map shows part of the border country of Transylvania lying between Hungary and Rumania.

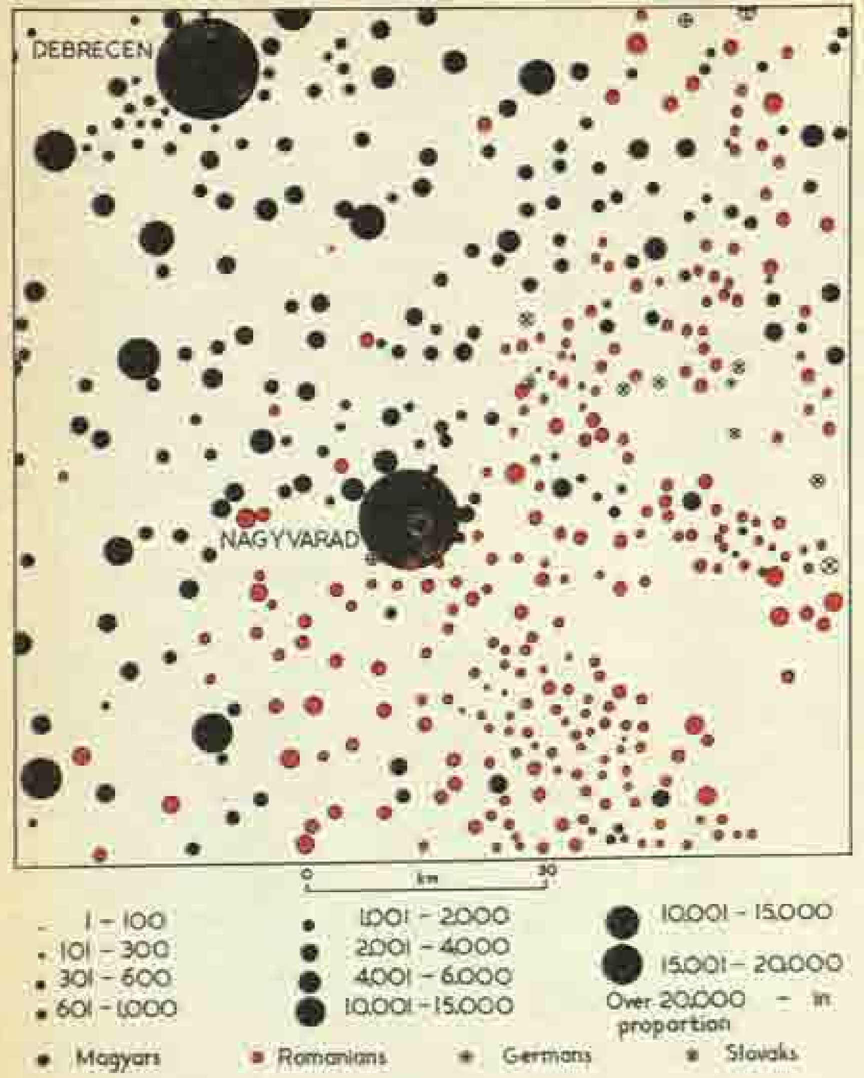


Fig. 155. Ethnographic Distributions by Proportional Circles

Based on *Roumanian Ethnographical Maps and their Value*, facing p. 34. Institute of Political Science (Budapest, 1942). Data from various inter-war censuses.

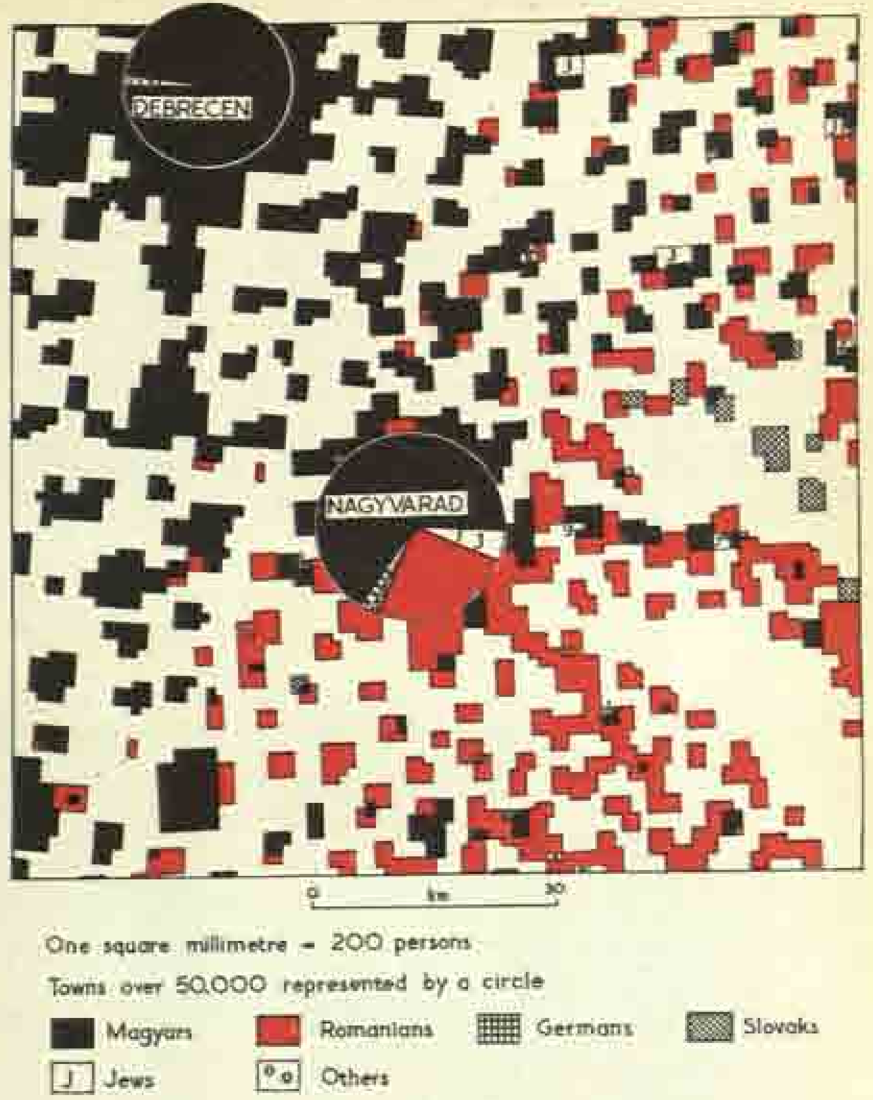


Fig. 156. Ethnographic Distributions by Grouped Squares

Based on *Ethnographical Map of Central Europe*, Institute of Political Sciences (Budapest, 1942). Data from various inter-war censuses.

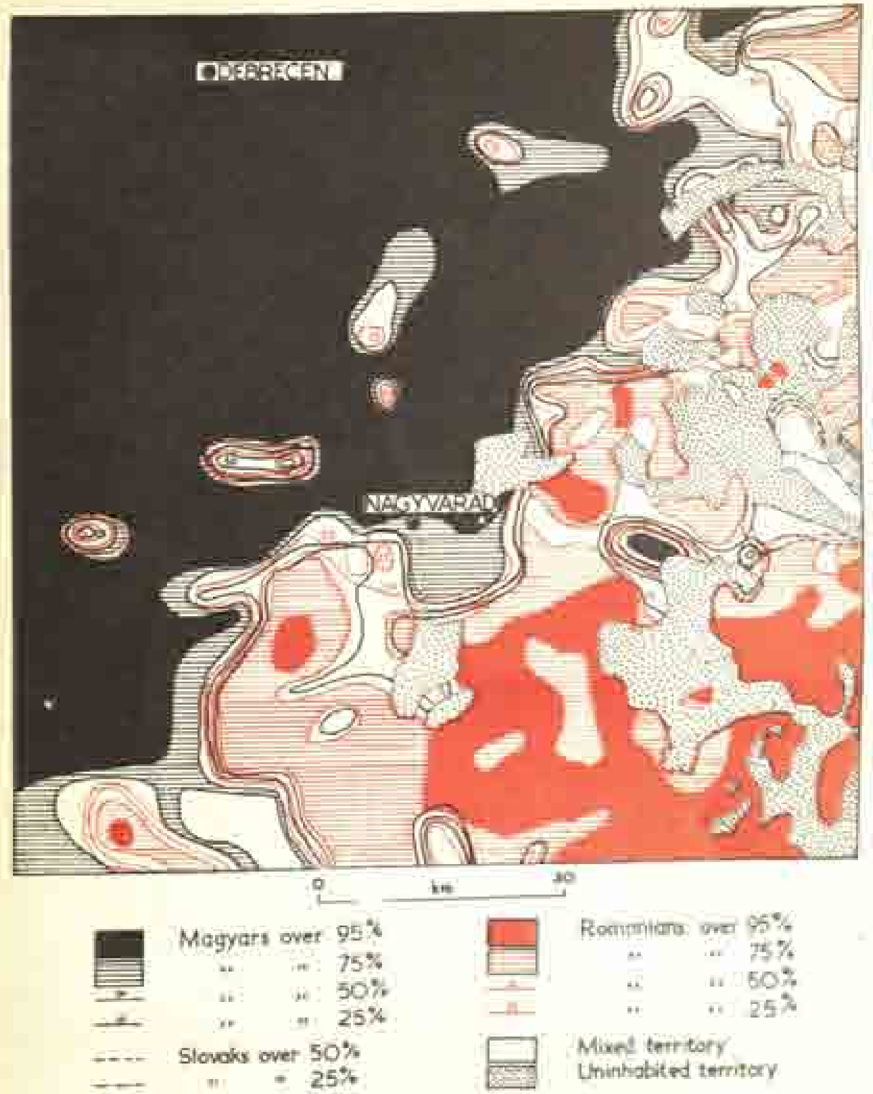


Fig. 157. Ethnographic Distributions by Isopleths

Based on 'Hungary, Atlas', *The peoples of Austria-Hungary, I* (N.I.S.D. 1919). Data from the Austro-Hungarian census of 1910.

found in many regions often leads to an overlap of symbols and causes difficulty in the drawing and in the interpretation of the map, and second, that the eye has difficulty in equating the symbol to the area it represents and the method does not readily convey density of population.

Proportional squares and circles may be effectively employed to show ethnic structure of population (Fig. 155),[1] occupational structure (Fig. 111), and also to show migration, especially in-migration to large towns, and time changes in the totals of populations.[2]

Proportional Spheres and Cubes

To overcome the disadvantage of overlap, proportional spheres or cubes may be used instead of circles and squares. The introduction of the third dimension enables a greater range of densities to be more effectively shown (see pp. 23-4). The symbols have to be shaded to create the illusion of sphericity (Fig. 133). A further refinement may be introduced by tinting the spheres according to the major industrial activity of the population in each centre; thus an additional indication of economic structure is given.[3] Distributions of occupations may also be shown by spherical symbols, because they can be grouped together without difficulty, providing that the classification is not too complex.

Dots and Circles

Two or more techniques in conjunction may profitably be employed to overcome some of the disadvantages commonly associated with a single technique. Dots and circles can be used, for example, to depict the distribution of population, particularly on a continental scale. Thus the dots may show the scatter of rural population, the circles may represent the population of towns (Fig. 131).[4]

In a composite map of this type, it is desirable that the symbols should be related to one another, so that the size of the dot is commensurate with the size of the circle. If a dot of one-tenth of an inch in diameter represents, say, 10,000 persons, a city of a million should

[1] See an excellent map of nationalities by proportional-squares method in l'Académie Tchèque, *Atlas de la République Tchécoslovaque* (Prague, 1935).

[2] See, for example, Ministry of Town and Country Planning, Population Maps, *op. cit.*

[3] See, for example, *Ekonomisk-Geografisk Karta över Sverige*, 1:1,000,000 (based on the 1940 Census and prepared by W. William-Olsson, Stockholm).

[4] W. Coulter, 'A Dot Map of Distribution of Population in Japan', *Geographical Review*, vol. 16 (New York, 1926).

be represented by a circle one inch in diameter. Expressed mathematically, the relationship is as follows:

$$\frac{\textit{Diameter of Circle}}{\textit{Diameter of Dot}} = \frac{\sqrt{1{,}000{,}000}}{\sqrt{10{,}000}} = \frac{10}{1}$$

A dot value of 10,000 is often too high to portray rural population distribution, even on a continental scale. If a smaller value is used, the circles representing urban population centres become correspondingly bigger. Even if they are drawn as rings, in order not to obscure neighbouring rural distributions, their size becomes impracticable. For example, a dot value of one hundred could be usefully employed to show the distribution of the rural population in Australia, but as some of the great Australian cities have populations exceeding the million mark, these would have to be represented by circles ten inches in diameter.

Dots and Spheres

To make the symbols for rural and urban population commensurate and yet practicable to draw, the urban populations may be shown in three dimensions by means of cubes or spheres. In the case of the Australian population distribution quoted above, the 'million' cities could each be represented by sphere, the diameter of which would be $\sqrt{10}$ inches, a much more practicable size to draw. This method of showing population distribution has many advantages, and conveys a good impression of density. It was first used with effect by Sten de Geer, the Swedish geographer.[1]

Grouped Squares

Probably the most satisfactory manner of depicting a complex ethnic structure is by means of symbols grouped in that locality where the population is known to be densest. Information has to be obtained by reference to the settlement pattern from large-scale topographical maps.

Some care is needed in the choice of size of symbol for this type of map. It depends on the range of density of population which occurs within the area under consideration. It is not necessary to calculate the scale of symbol from the situation as it exists on the ground; it is more simple to work directly from the base-map selected. If the area on the map of the administrative unit which has the greatest density is calculated to be 2·5 square centimetres and the population of the

[1] S. de Geer, 'A Map of the Distribution of Population in Sweden: Method of Preparation and General Results', *Geographical Review*, vol. 12 (New York, 1922). The maps themselves were published in the form of an atlas—*Karta över Befolkningens Fördelning i Sverige den 1 Januari, 1917*, 1:500,000, 12 plates (Stockholm, 1919).

unit is, say, 40,000, then the density on the map, i.e. the scale of symbol to be adopted, must not be more than:

$$\frac{40{,}000}{2\cdot5}\ \textit{persons per sq. cm.} = 160\ \textit{persons per sq. mm.}$$

If this scale of symbol were adopted, every 160 persons in each ethnic group would be represented on the map by a shaded area one millimetre square. The millimetre squares are built up into shapes, or in the case of towns incorporated into circles, and placed in position on the map according to information gleaned from an examination of topographical maps (Fig. 156). Thus the administrative unit with a population of 40,000 mentioned above would be fairly well covered

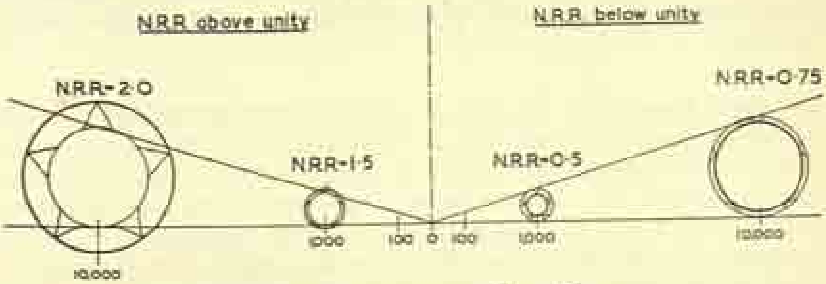


FIG. 158. NET REPRODUCTION RATE SYMBOLS

Circles with thin lines indicate sizes of actual populations and circles with thick lines indicate the quotient of population total multiplied by current net reproduction rate. Outward-facing points denote potential increase and inward-facing points denote potential decrease in the respective sizes of populations.

with squares arranged in a pattern corresponding to its shape. A unit with a population of only 160, however, would have only one millimetre square placed in the vicinity of the largest village or habitation. Any population too small to show is added to the population of a neighbouring unit, so that every person in each ethnic group is represented on the final map.

One difficulty in the choice of scale of symbol is likely to be encountered. Where very large cities have to be considered they will inevitably dictate the scale to be adopted, with disastrous consequences for the representation of rural populations. Accordingly, these cities should be treated separately—represented perhaps by circular diagrams on the margins of the map, or by proportional spheres grouped *in situ*. If the former are used, care should be taken to adopt the same symbol scale as for the rest of the map, and to show the position of the towns by rings on the map, the rings being proportional in size to the total population.

Special Proportional Symbols

Special symbols may be designed to show distribution of particular features of population structure. For example, H. J. Fleure devised special symbols to show the distribution of net reproduction rate in Europe (Fig. 158).[1] The symbols in this case were devised to show population totals and negative and positive net reproduction rates according to their numerical values.

Isopleths

The use of isopleths has only a limited application in the case of population maps. They are used mainly to depict (*a*) population distributions on a continental scale, where it is desired to smooth out local variations in order to get a broad appreciation of population density-zones; (*b*) population potential; and (*c*) ethnographic distributions.

Population Density

The administrative unit has to be chosen with care for the construction of maps showing density of population.[2] To use communes, for example, in the case of France, or parishes in the case of Great Britain, would lead to great difficulty in the interpolation of isopleths because of the detail involved. Points for interpolation are arbitrarily fixed in the geographical centre of the administrative unit, or over the biggest centre of population within that unit, their value being the mean density of the population in the unit concerned. Skill in such interpolation only comes with practice. The spotting of key isopleths enables the others to be quickly drawn. It is often necessary to construct a dispersion graph to help decide the isopleth intervals to be selected.

It has been noted above that the chief disadvantage of the isopleth technique is its unsuitability for showing details of distribution. In areas where great variations in density occur, key isopleths are impossible to discern and the whole map becomes a series of concentric circles centred on the towns. This disadvantage can be offset if the town populations are shown by spheres, and the rural populations are shown by isopleths; this method has been used effectively to depict distribution of populations in, for example, central Oklahoma.[3]

[1] H. J. Fleure, *Problems of Population in Europe* (Manchester, 1942).

[2] Techniques of construction are discussed in J. W. Alexander and G. A. Zahorchak, 'Population Density Maps of the United States; Techniques and Patterns', *Geographical Review*, vol. 33 (New York, 1943).

[3] C. J. Bollinger, 'A Population Map of Central Oklahoma', *Geographical Review*, vol. 20 (New York, 1930).

Population Potentials

Isopleths may also be used with effect in the plotting of *potentials* of population.[1] The word potential here is used in the same sense as in physics; the gravitational influence of a planet on the earth, for example, may be expressed as Md, where M is its mass and d the distance away from the earth. The influence of any concentration of population from one part of the earth to another may be expressed as the number of people in that concentration multiplied by its distance to the spot at which its potential is being assessed. This potential

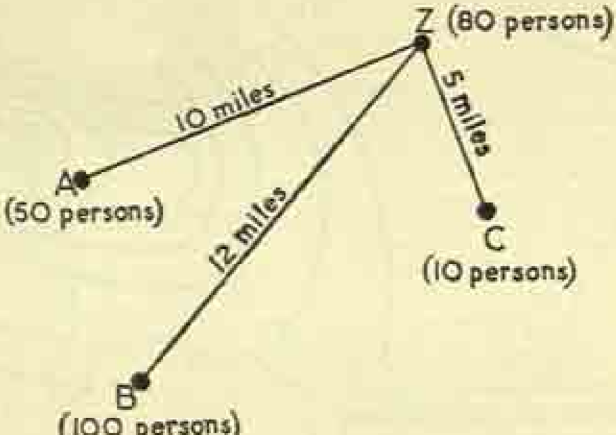


FIG. 159. CALCULATION OF POPULATION POTENTIAL

has obviously great cultural, social, economic and even political significance. It may be mapped by means of isopleths with an interval expressed in terms of persons per mile. In the case of Europe, for example, the points for interpolation may be located in the centre of administrative units of a size approximating to that of a county. The potential of each of these points has then to be calculated by the formula:

$$nd = P$$

where n is the number of persons, d is the distance and P is the potential.

The population potential at each county centre will be the sum of the influence of all other centres upon it, plus its own influence upon itself. An example will make this clear. Consider Fig. 159, which

[1] J. Q. Stewart, 'Empirical Mathematical Rules concerning the Distribution and Equilibrium of Population', *Geographical Review*, vol. 37 (New York, 1947).

incorporates four concentrations of population at A, B, C and Z. The potential in terms of persons per mile at Z will be as follows:

From A to Z:	$50 \times 10 =$	500 *persons per mile*
From B to Z:	$100 \times 12 =$	1,200 *persons per mile*
From C to Z:	$10 \times 5 =$	50 *persons per mile*
Own (Z)	$=$	80 *persons per mile*
Potential at Z	$=$	1,830 *persons per mile*

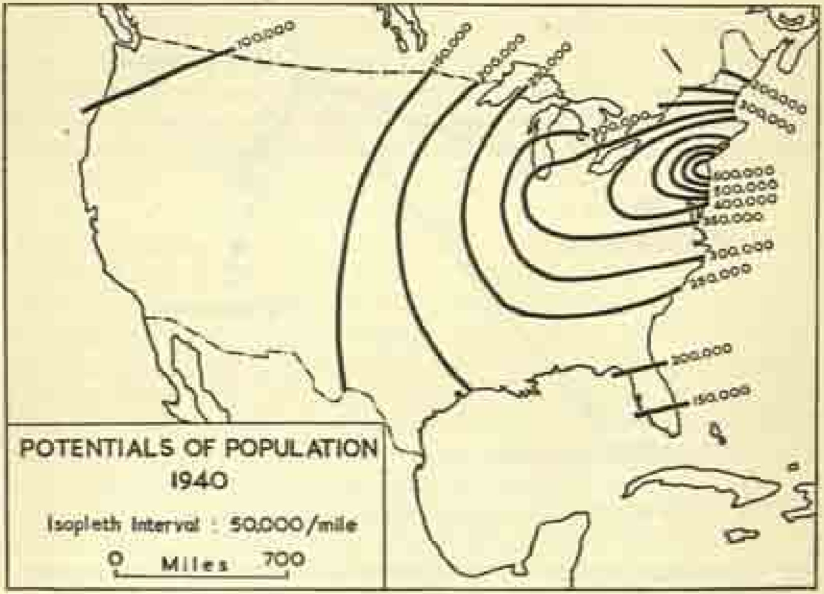


FIG. 160. POPULATION POTENTIALS BY ISOPLETHS FOR THE U.S.A.

Based on J. Q. Stewart, 'Empirical Mathematical Rules concerning the Distribution and Equilibrium of Population', *Geographical Review*, vol. 37, p. 476 (New York, 1947).

It may be appreciated that a considerable amount of labour is necessary to calculate potentials at each point when a large number have to be considered. When the potentials have been computed and plotted, the isopleths are interpolated in the usual manner. The completed maps often reveal extraordinary concentrations of potential at one point within a land mass of continental size (Fig. 160).

Ethnographic Distributions

Maps depicting the distribution of nationalities by isopleths have certain advantages, for they show comparative concentrations of the

various ethnic groups in zones, they indicate sharp divides between one group and another, and they delimit mixed areas.[1] Data for the interpolation of isopleths are worked out separately for each ethnic group. For example, the percentage of group *X* to the total population is obtained for all the administrative units under consideration. The percentages are plotted in the centre of the unit concerned, and then the isopleths are drawn at suitable intervals of 10, 20 or 25 per cent, according to the detail required. Where a number of groups has to be considered, isopleths must be drawn in colour in order to be distinguishable (Fig. 157).

Divided Circles

Divided circles ('pie-graphs') are widely used to illustrate features of the population structure. The circles are divided to show constituent elements in the population of any area. There are two varieties: (*a*) proportional divided circles, which vary in size according to the respective totals of population under consideration; and (*b*) comparable divided circles, which are of standard size, and which are usually employed where the population totals have such a wide range that proportional circles would vary in size from a dot to a large circle. Both varieties may be used to show the ethnic, racial, social, occupational, industrial and age structure of the population. Most useful are two-element divided circles to show such fundamental proportions as rural versus urban population, migrants versus native-born, residential versus working population and ethnic minority (see pp. 219-24) versus majority. Another useful function of these diagrams is to show time-changes from one decade to another, for example, in population totals or in the numbers of migrants. It is not intended to discuss all these applications here, but the principles of construction of divided circles may be illustrated with reference to the mapping of the industrial structure of population in some twenty Lancashire towns.

Located Divided Circles

The data for this example are drawn from Table 4 of the *Industry Tables* of the Census of England and Wales for 1921, in which details are listed of the number of persons engaged in some 400 industries, based on place of work. There are many ways in which these industrial data may be classified for the purpose of cartographical illustration. In this case they have been grouped into seven categories on the basis of 'function', and each category may be said to represent a functional activity of the population. The total number of persons

[1] B. C. Wallis, 'The Distribution of Nationalities in Hungary', *Geographical Journal*, vol. 47 (London, 1916).

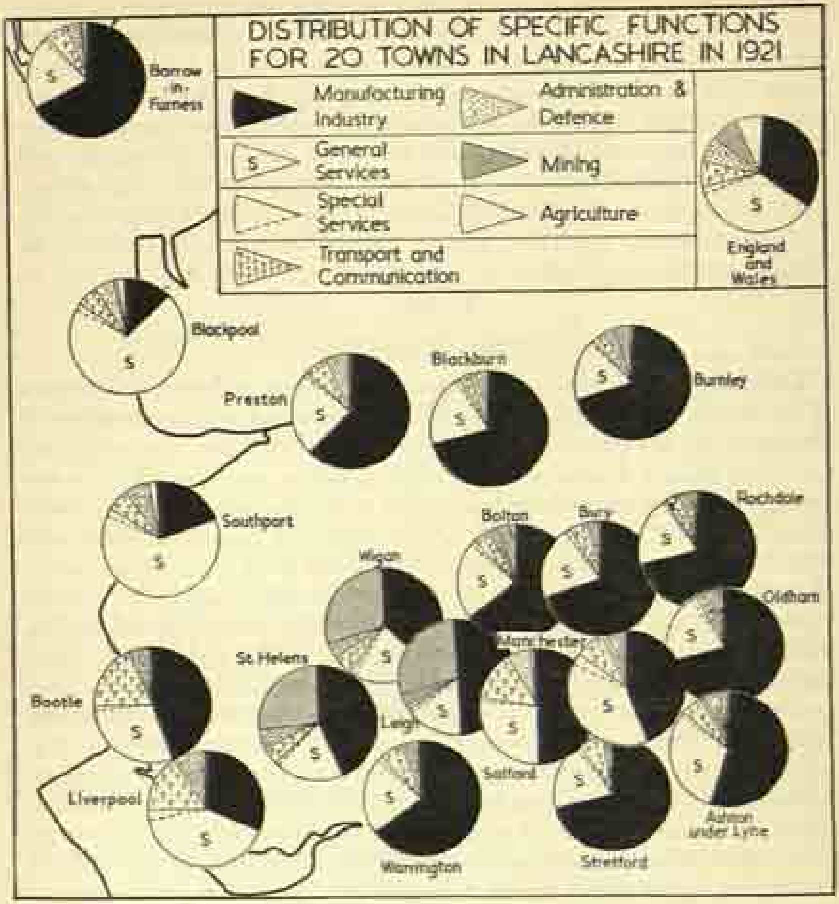


FIG. 161. LOCATED COMPARABLE DIVIDED CIRCLES

Source of data: *Census of England and Wales, 1921, Industry Tables* (London, 1925).

By comparing the diagram for each town with that for England and Wales as a whole, some idea of the amount of specialization of function for each of the towns can be estimated. The majority of Lancashire towns fall into the manufacturing category. Their crowded distribution leaves but a limited urban field for each town and services are under-developed. The extraordinary concentration of services in Southport and Blackpool is immediately apparent. Manchester approximates most closely to the average distribution of functions, thus its metropolitan status is reflected. In contrast Liverpool emerges as a transport town but with services above the average.

engaged in each category has been calculated as a percentage of the total engaged in all seven and the results have been plotted (Fig. 161).

Columnar Diagrams

There are essentially three forms of columnar diagram which may be used to illustrate population data: (*a*) simple columns to depict quantitative data; (*b*) compound, in which each column is subdivided to show structural aspects; and (*c*) superimposed, in which departures from normal distributions are shown to illustrate regional variations.[1]

Located Superimposed Columnar Diagrams

The location and superimposition of columnar diagrams deserves fuller treatment, both as an example of the principle of columnar representation of population data, and as an example of how columnar diagrams may be adapted to show regional variations. The example taken illustrates data drawn from the *Industry Tables* of the Census of England and Wales in 1921. The data are based on place of work and not on place of enumeration, so that they can be used to indicate location of industry (see p. 224). For the purposes of the illustration, the total number of persons engaged in manufacturing of all types in each of the ten biggest towns in Cheshire in 1921 has been considered, and these totals have been broken down into six major categories. The number of workers in each category in each town has been expressed as a percentage of the total workers in all six categories. These percentages have been expressed in the form of columns arranged in a horizontal series to facilitate mapping. These columnar diagrams have been superimposed, in each case, on another which depicts the percentages for England and Wales as a whole (Fig. 162). By this method the manufacturing structure of the population in each town is boldly depicted and the degree of localization of the six categories of industrial occupations may be quickly appreciated by inspection.

Pyramids

Columns constructed to represent specific quantitative population data may be arranged in the form of a pyramid. Pyramids of this type are employed primarily in the analysis of population growth, and of population composition.

Age and Sex Pyramids

The simplest method of representing the sex and age structure of a population is to represent it in the form of a pyramid built up in

[1] A number of well-executed columnar diagrams is to be found in United States Department of Commerce, Bureau of Census, *Statistical Atlas of the United States* (Washington, 1935).

age groups, males on one side, females on the other, and with the base representing the youngest group, the apex the oldest (Fig. 163). These pyramids may take the form of groups for individual years, in which case there may be as many as ninety or more tiers in the pyramids, or, more usually, of five-year or quinquennial groups. Pyramids based on quinquennial groups provide the geographer with as sufficient

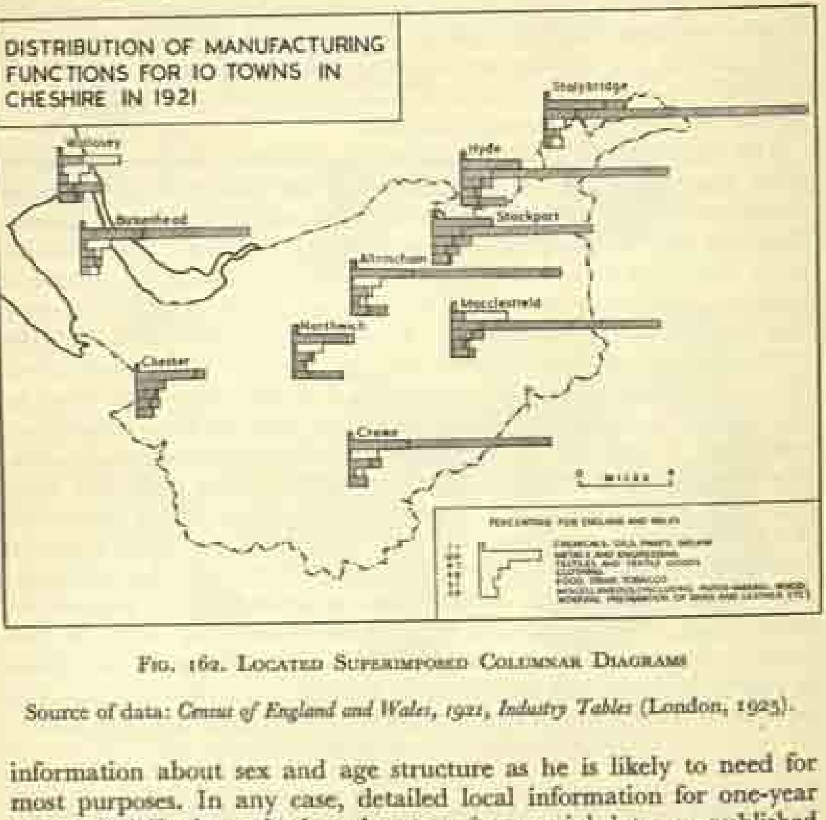


FIG. 162. LOCATED SUPERIMPOSED COLUMNAR DIAGRAMS

Source of data: *Census of England and Wales, 1921, Industry Tables* (London, 1925).

information about sex and age structure as he is likely to need for most purposes. In any case, detailed local information for one-year groups is difficult to obtain, whereas quinquennial data are published in international returns, in individual census returns, and occasionally in special returns of the Registrar General. There are slight variations in the methods by which quinquennial data may be plotted in the form of pyramids; these are compared in Fig. 163.

The Absolute Method. The data are plotted directly from the absolute quinquennial totals given in the census returns, after a suitable scale has been chosen (example *a*). If a linear scale only is used, all the pyramids will be the same height, the variation will be in their relative widths. If the width of each tier in the pyramid is made proportional

to its length, the relative heights of the pyramids will vary as well as their widths (example *b*). The pyramids are then orthomorphic and their shapes may be easily compared.[1] Even so, the pyramids will vary enormously in size, from that of a large town, for example, to that of a small rural community.

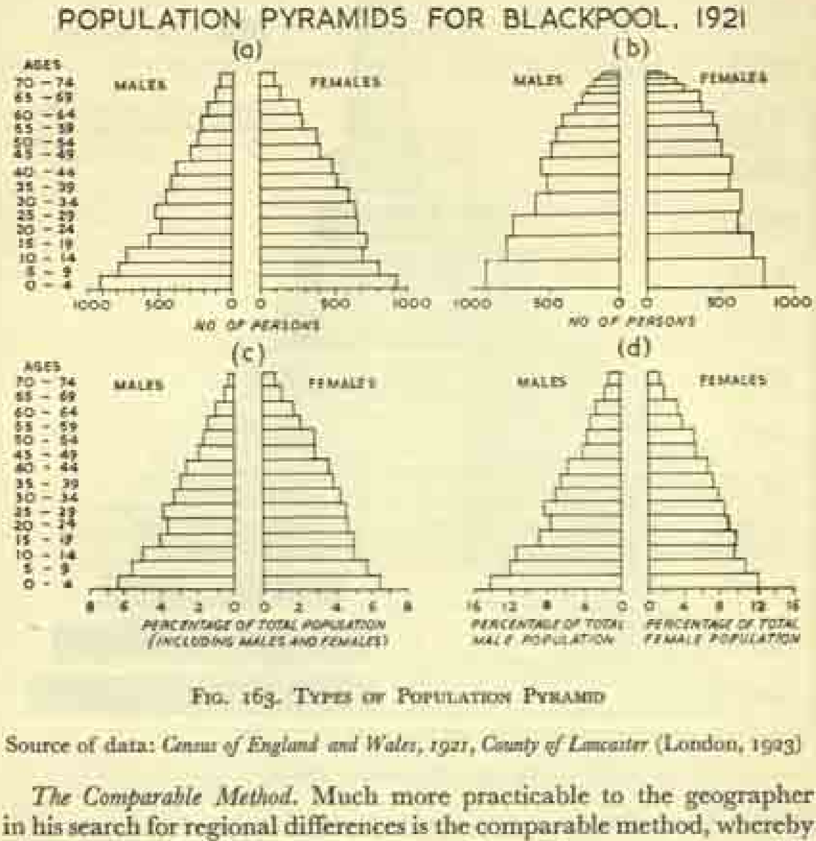


Fig. 163. Types of Population Pyramid

Source of data: *Census of England and Wales, 1921, County of Lancaster* (London, 1923)

The Comparable Method. Much more practicable to the geographer in his search for regional differences is the comparable method, whereby all age groups are given percentage values. There are two possible ways of carrying out this method. Either each male age group may be expressed as percentages of the total male population in each community, and similarly each female group (example *d*),[2] or, each male and each female group may be expressed as percentages of the total population of each community (example *c*). The latter method has

[1] Pyramids for European populations are thus contructed in a map in D. Kirk (*op. cit.*).

[2] For an application, see a series of pyramids in H. Gille, 'Demographic History of the Northern European Countries', *Population Studies*, vol. 3 (Cambridge, 1949–50).

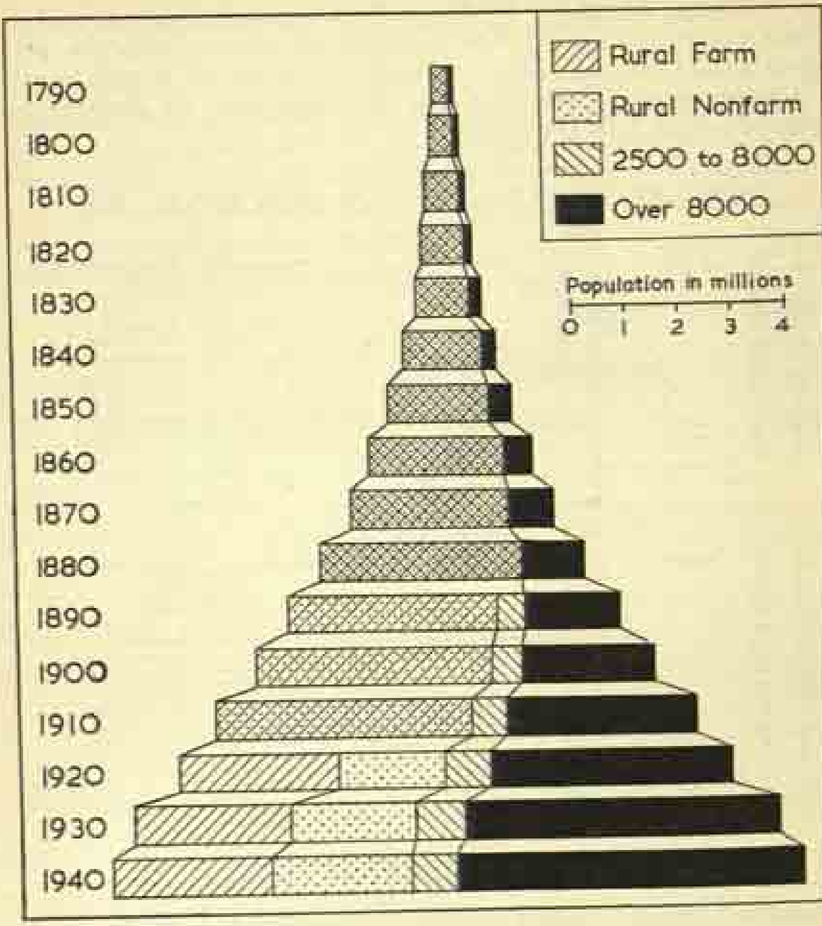


FIG. 164. COMPOUND PYRAMID

Modified from a diagram in T. L. Smith, *Population Analysis*, p. 318 (New York, 1948).

Each tier has been made proportional in length to the total of population for each census year. The tiers are then subdivided into rural and urban elements in the population according to the categories adopted in the various censuses. From 1790 to 1880 only two categories were recognized and places with a population of over 8,000 were regarded as being urban in character. From 1890 to 1910 there were three divisions when the urban category was extended to include places with a population of over 2,500. From 1920 to 1940, the rural category was subdivided into rural farm and rural nonfarm.

the advantage of giving a realistic total view of sex and age variations in each community considered (Fig. 166).

Compound Pyramids

Pyramids may be used to illustrate features other than sex and age structure. For example, the tiers in the pyramid may be made to

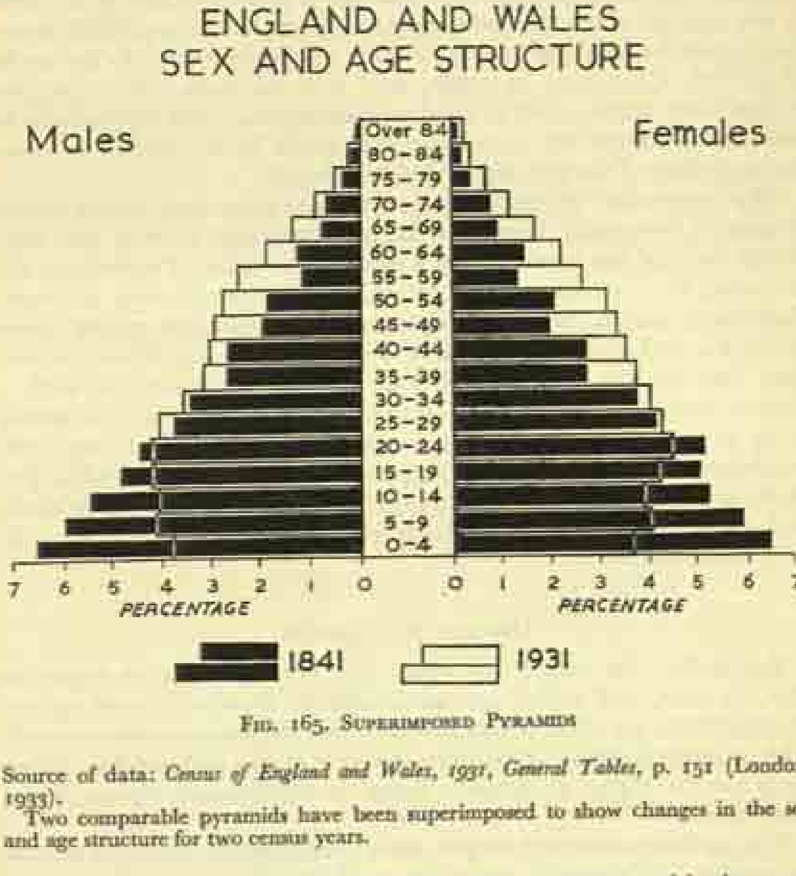


FIG. 165. SUPERIMPOSED PYRAMIDS

Source of data: *Census of England and Wales, 1931, General Tables*, p. 151 (London, 1933).

Two comparable pyramids have been superimposed to show changes in the sex and age structure for two census years.

represent decennial totals of migrants into a country, with the apex indicating the earliest, the base the latest returns. Each tier is then subdivided to show ethnic structure, age structure, etc., of the migrant stream. Decennial totals of population for a region or for a country may also be portrayed in this way, the subdivisions in this case being made to depict rural versus urban population. These pyramids are best constructed with a space left between each tier, across which lines are drawn to join the component subdivisions (Fig. 164).

Superimposed Pyramids

Age and sex pyramids may be superimposed to show structural changes in the population of any given region over a period of time. Similarly, pyramids representing populations of different regions may be superimposed for comparative purposes, or pyramid superimpositions may be made of an actual population upon that of a hypothetical 'stationary' population.[1] The latter procedure has great value in the analysis of the rhythm of population growth. Comparable pyramids must be used, of course, if such comparisons are to be made (Fig. 165). Care must be taken, also, that the data utilized applies to the same region, and it is often necessary to consider changes in enumeration areas that may have been made in the interim between the recording of the two sets of data employed.

The 'projecting' of populations—a form of forecasting future populations—is frequently illustrated by superimposing present and projected age and sex pyramids for a particular region.[2] Populations are projected for a variety of reasons, principally for planning purposes. Projections may be made on the assumption either that current rates of fertility and mortality are likely to continue into the future, or that they may decline, or that they may behave in accordance with a 'logistic curve', that is, a curve continued according to logical expectations. It is patent that if age-sex specific birth- and death-rates are available, the projection of a population presents no difficulty. But birth- and death-rates do not remain constant for any length of time, and consequently projections made on these assumptions serve only a limited purpose.

Divided Rectangles

Rectangles, the lengths of which are usually made to represent 100 per cent, and which are subdivided to show structural aspects of population, are generally employed where comparisons are required. The comparisons may be between one population and another, either for a specific region at different times, or for different regions at the same time.[3]

The method serves well to show shifts in occupations from one decade to another or changes in age structure. Individual rectangles may be constructed to show the data for each decade, or all the data may be plotted in one rectangle and related plottings joined to form con-

[1] For an example, see P. Vincent, 'Retraitres et Immigration', *Population*, vol. 1 (Paris, 1946).

[2] See method illustrated in F. W. Notestein, *The Future Population of Europe and the Soviet Union* (Geneva, 1944).

[3] See examples in *Statistical Atlas of the United States*, *op. cit.*

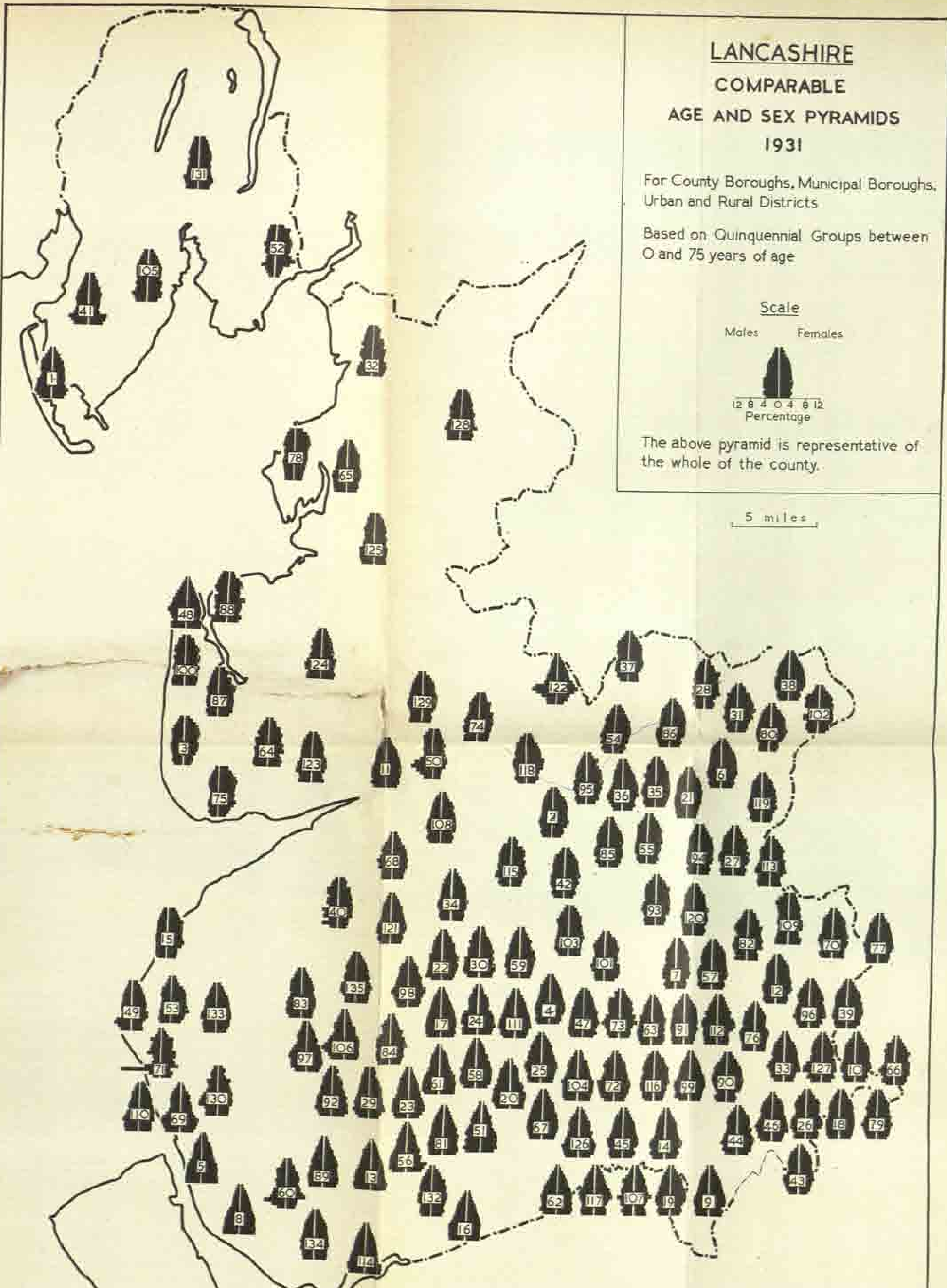
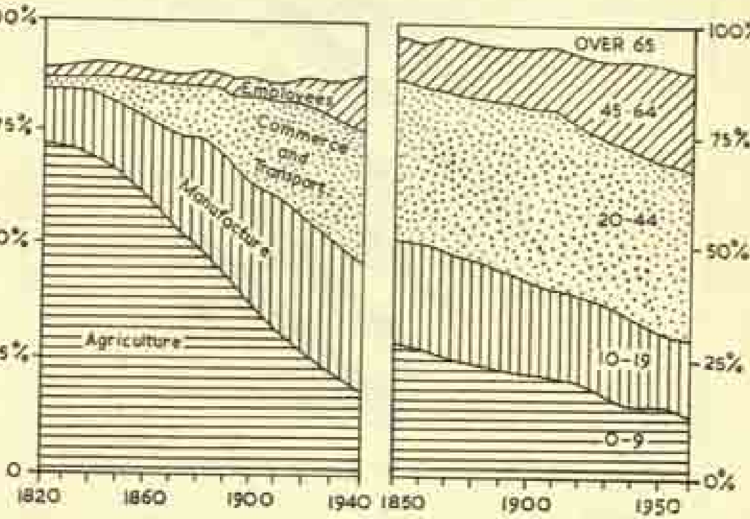


FIG. 166. DISTRIBUTION OF SEX AND AGE STRUCTURE BY COMPARABLE PYRAMIDS
Source of data: *Census of England and Wales, 1931, County of Lancaster*, pt. 1 (London, 1933).

The references on the map are as follows: *County Boroughs*—1. Barrow in Furness; 2. Blackburn; 3. Blackpool; 4. Bolton; 5. Bootle; 6. Burnley; 7. Bury; 8. Liverpool; 9. Manchester; 10. Oldham; 11. Preston; 12. Rochdale; 13. St. Helens; 14. Salford; 15. Southport; 16. Warrington; 17. Wigan; *Municipal Boroughs and Urban Districts (over 50,000)*—18. Ashton under Lyne; 19. Stretford; *(under 50,000)*—20. Abram; 21. Accrington; 22. Adlington; 23. Ashton-in-Makerfield; 24. Aspull; 25. Atherton; 26. Audenshaw; 27. Bacup; 28. Barrowford; 29. Billinge and Winstanley; 30. Blackrod; 31. Brierfield; 32. Carnforth; 33. Chadderton; 34. Chorley; 35. Church; 36. Clayton-le-Moors; 37. Clitheroe; 38. Colne; 39. Crompton; 40. Croston; 41. Dalton in Furness; 42. Darwen; 43. Denton; 44. Droylsden; 45. Eccles; 46. Failsworth; 47. Farnworth; 48. Fleetwood; 49. Formby; 50. Fulwood; 51. Golborne; 52. Grange; 53. Great Crosby; 54. Great Harwood; 55. Haslingden; 56. Haydock; 57. Heywood; 58. Hindley; 59. Horwich; 60. Huyton with Roby; 61. Ince in Makerfield; 62. Irlam; 63. Kearsley; 64. Kirkham; 65. Lancaster; 66. Lees; 67. Leigh; 68. Leyland; 69. Litherland; 70. Littleborough; 71. Little Crosby; 72. Little Hulton; 73. Little Lever; 74. Longridge; 75. Lytham St. Annes; 76. Middleton; 77. Milnrow; 78. Morecambe and Heysham; 79. Mossley; 80. Nelson; 81. Newton in Makerfield; 82. Norden; 83. Ormskirk; 84. Orrell; 85. Oswaldtwistle; 86. Padiham; 87. Poulton le Fylde; 88. Preesall; 89. Prescot; 90. Prestwich; 91. Radcliffe; 92. Rainford; 93. Ramsbottom; 94. Rawtenstall; 95. Rishton; 96. Royton; 97. Skelmersdale; 98. Standish with Langtree; 99. Swinton and Pendlebury; 100. Thornton Cleveleys; 101. Tottington; 102. Trawden; 103. Turton; 104. Tyldesley with Shakerley; 105. Ulverston; 106. Upholland; 107. Urmston; 108. Walton le Dale; 109. Wardle; 110. Waterloo with Seaforth; 111. Westhoughton; 112. Whitefield; 113. Whitworth; 114. Widnes; 115. Withnell; 116. Worsley; *Rural Districts*—117. Barton upon Irwell; 118. Blackburn; 119. Burnley; 120. Bury; 121. Chorley; 122. Clitheroe; 123. Fylde; 124. Garstang; 125. Lancaster; 126. Leigh; 127. Limehurst; 128. Lunesdale; 129. Preston; 130. Sefton; 131. Ulverston; 132. Warrington; 133. West Lancashire; 134. Whiston; 135. Wigan.

tinuous lines (Figs. 167–8). Such a diagram is, of course, a form of compound graph. The distribution of changes in structure may be shown by means of rectangles located on a suitable base-map. Thus the changes in the ethnic structure of Greek Macedonia between 1912 and 1926 have been shown by a series of twin rectangles, one of the structure in 1912 and the other of the structure in 1926.[1]



FIGS. 167–8. DIVIDED RECTANGLES OF OCCUPATION AND AGE STRUCTURE

Based on W. S. Thompson, 'La Population des Etats-Unis d'Amérique', *Population*, vol. 3, pp. 123 and 125 (Paris, 1948).

Fig. 167 shows changes in the percentage of paid workers over the age of 10 in the major occupational groups of the U.S.A. according to data derived from various census returns. The composite category of 'Others' is left unshaded.

Fig. 168 shows changes in the age structure of the population of U.S.A. according both to various census returns and to Thompson's own estimates for 1950–60.

Divided Strips

The divided strip method of showing distributional aspects of population structure is a variant of the divided rectangle method. It may be exemplified with reference to the ethnic structure of population. If the distribution of the relative proportions of various nationalities in an ethnically complex population has to be depicted on the basis of administrative units, the proportions of each nationality in each unit are first of all calculated on a percentage basis. They are then

[1] 'Ethnographical Map of Greek Macedonia showing the proportion of the different ethnographical elements in 1912 and in 1926', *Greek Refugee Settlement* (Geneva, 1926).

plotted on to the base-map, which consists of an outline of the administrative units, but with each individual unit divided into oblique strips of uniform width. Each adjacent strip represents 100 per cent, and these are divided to depict the ethnic structure of an administrative unit (Fig. 169).

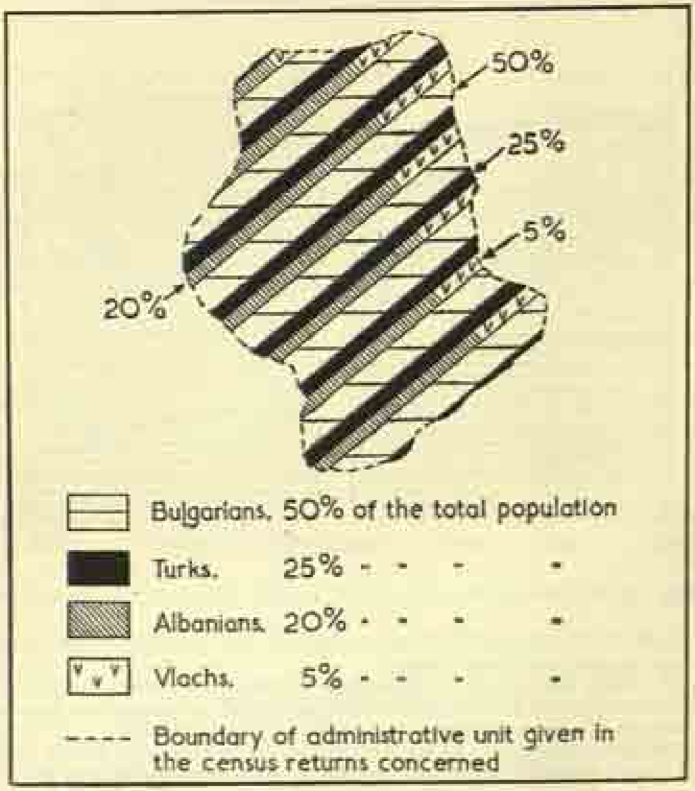


Fig. 169. Divided Strip Technique

Based on H. R. Wilkinson (*op. cit.*).

Star-Diagrams

Star-diagrams may be used in population studies to illustrate affinities of race, age structure, etc., between diverse population groups. Affinities are often measured, for convenience in mapping, by means of indices. Racial affinities as measured by a blood-group index may be considered here as an example of these methods. A variety of blood-group indices have been devised. Four major variables have

to be considered—the proportions of *A*, *O*, *B* and *AB* elements, respectively, present in each population group. In the population of the world in general, random tests suggest that these groups are present in the average proportions of *A*: 38 per cent; *O*: 37 per cent; *B*: 18 per cent; and *AB*: 7 per cent, although the proportions in local populations differ considerably from these averages.[1] N. Lahovary put forward the idea that one way of establishing the affinity of race between any two populations might be to compare their blood-group ratios and express the results in the form of an index, as follows:

	Population X	*Population Y*	*Differences*
A . .	53	40	13
O . .	27	45	18
B . .	13	10	3
AB . .	7	5	2
Totals . .	100	100	36

The 36-point difference acts as an index of racial affinity.

If a number of population groups is compared on this basis with any one population group, the resultant indices may be plotted diagrammatically as in Fig. 170. Alternatively, local deviations from the world average ratio may be calculated.

Scatter-Diagrams

Scatter-diagrams are used in population studies to give a graphic indication of the amount of correlation between two sets of statistical data. If the exact degree of correlation were required it would, of course, have to be computed mathematically (see p. 128).

The first step in the construction of a scatter-diagram is to group the values under consideration into convenient classes arranged in order of magnitude. One set of data is then plotted as ordinates and the other as abscissae. If when the values are plotted they tend to be grouped together along a diagonal line, some degree of correlation is manifest. If the correlation is perfect, all points would lie on one line, but this condition is rarely achieved when dealing with human affairs.

To illustrate the construction of a scatter-diagram, fertility ratio in Lancashire has been correlated with the proportion of males aged

[1] N. Lahovary, *Les Peuples Européens* (Paris, 1946).

15–60 in the total population of the county (Fig. 171). Some degree of correlation is to be observed from the diagonal scatter of the dots. The fertility ratio tends to rise as the proportion of males in the population increases.

Many examples of scatter-diagrams appear in demographic texts, but an interesting application of their use in the field of population geography is to be found in A. Stevens' paper on rural population (*op. cit.*).

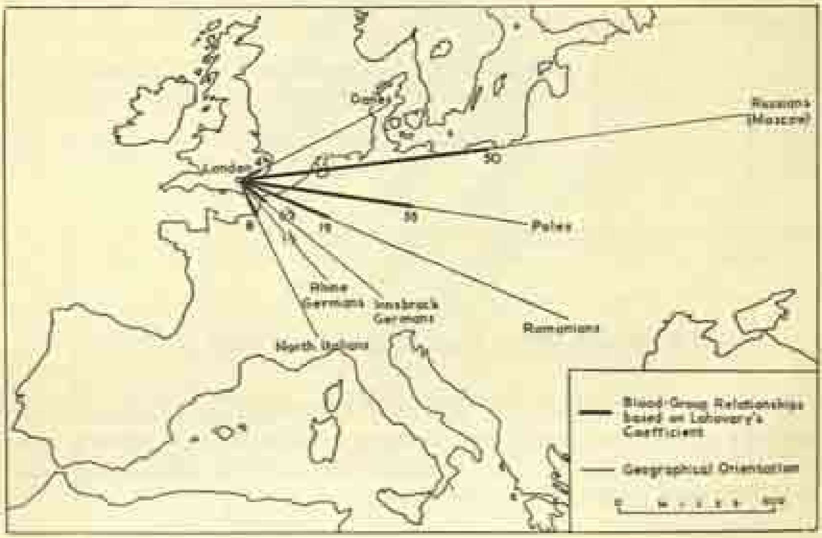


Fig. 170. A Star-Diagram of Racial Affinities

Source of data: N. Lahovary, *Les Peuples Européens* (Paris, 1946).

The map shows racial affinities between a selected group of English (from London) and certain other European groups as measured by blood-group reactions. The lengths of the thickened lines have in each case been made proportional to the coefficient, e.g., for Poles, the coefficient is 35, therefore the thick line represents 35 units. The shorter the thick line, the closer is the affinity between any two groups.

Arrows

Arrows are used chiefly in population studies as a method of showing the movement or migration of population. Only certain categories of data can be illustrated by this method because, to avoid confusion, only a limited number of arrows may be placed on any one map. They may be used to show: (*a*) the main currents of movement of seasonal workers, for example, in the case of the U.S.A., those of fruit

and truck workers, berry-crop harvesters, and wheat harvesters;[1] (*b*) seasonal movements of nomadic or semi-nomadic communities;[2] (*c*) daily movement of workers from place of residence to place of work;[3] (*d*) the balance of migration between countries and between states;[4] (*e*) migration from countryside to town; and (*f*) generalized patterns of direction of migrations.[5]

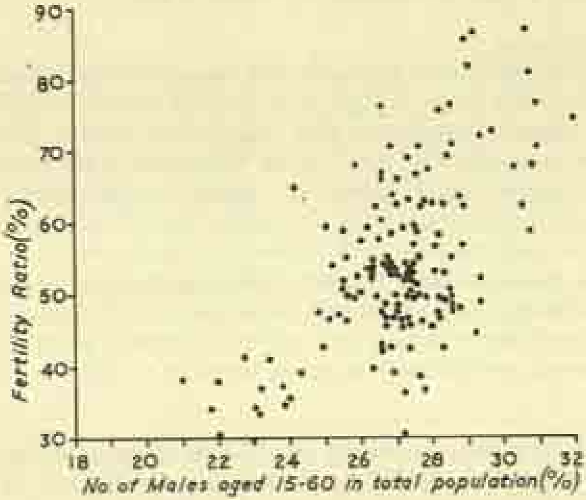


FIG. 171. A SCATTER-DIAGRAM

Source of data: *Census of England and Wales, 1881*, vol. 3 (London, 1883).

The fertility ratio in each administrative district in Lancashire in 1881 (as measured by *No. of Children under 5 / No. of Females aged 15–50 × 100*) has been plotted against the relative proportion of males in the population aged 15–60 (as measured by *No. of Males aged 15–60 / Total population × 100*).

Where arrows proportional in thickness to totals of migrating population are used, the map tends to become obscured by a few thick arrows. To overcome this difficulty arrows and proportional symbols

[1] Differentiated arrows are used by T. L. Smith (*op. cit.*) to show such movements in a map entitled, 'Streams of Inter-state Farm Labor Migration [in the United States]'.

[2] See such movements shown in a map, 'Formes de la Propriété Rurale', in J. Cvijić, *La Péninsule Balkanique* (Paris, 1918).

[3] A good example of such a map, using arrows of proportional thickness, is to be found in F. Longstreth Thompson, *Merseyside Plan, 1944* (London, 1945).

[4] Illustrated by a map in E. M. Kulischer, *Europe on the Move* (New York, 1948).

[5] J. Cvijić, 'Courants Métanastasiques dans le peuplement des Pays Serbe' (*op. cit.*).

may be combined. This method has been used to good effect in a very full study of migration in the United States.[1]

Line-Graphs

So great is the variety of line-graph employed to illustrate population data, that only a selected number can be discussed here. The elemental principles of graphical analysis are summarized, and a few rather special graphs are discussed in more detail.

Simple Line-Graphs

Absolute Growth Graphs. Probably the most familiar graph used in population studies shows changes over a period of time. Totals of population are plotted as ordinates and time values, usually in decennial periods, as abscissae (Fig. 172). After the points have been plotted, they are conventionally joined by short straight lines, although strictly speaking the implication of uniform growth during intercensal periods to be inferred from such a procedure is erroneous.

Percentage Increase Graphs. Instead of plotting absolute totals of population, percentage increase values are plotted as ordinates. The points are joined and the resulting line is conventionally assumed to show rates of growth, which may be either negative or positive (Fig. 172).

Polygraphs

Trends in Birth-Rate, Death-Rate and Natural Replacement. In all cases, rates in values per thousand are plotted as ordinates and time values as abscissae. Values may be plotted independently and points joined to form simple line-graphs, but more usually birth- and death-rates are plotted on one diagram and natural replacement referred by inspection (Fig. 173).

Birth, death and replacement rates may be broken down for further analysis into age-specific rates. The graphs are constructed in the same way, but the values for different age and sex groups are plotted as ordinates instead of general values. Age-sex specific rates may be still further broken down to give racial values, such as coloured and white.[2] It is customary to show data from a complete generation on one graph, so that some care is needed to differentiate between any multiple lines which might cross (see p. 4). Age-sex specific rates are generally plotted for quinquennial rather than for individual yearly values, but an exception is often made in the case of infants under one year of age, because of the relative frequency of deaths at this time of life compared with other ages.

[1] C. J. Galpin and T. B. Marny, *Inter-State Migrations among the Native White Populations as indicated by Difference between State of Birth and State of Residence. A Series of Maps based on the Census, 1870–1930* (U.S. Dept. of Agriculture, Washington, 1934).

[2] For example, see graphs in T. L. Smith (*op. cit.*).

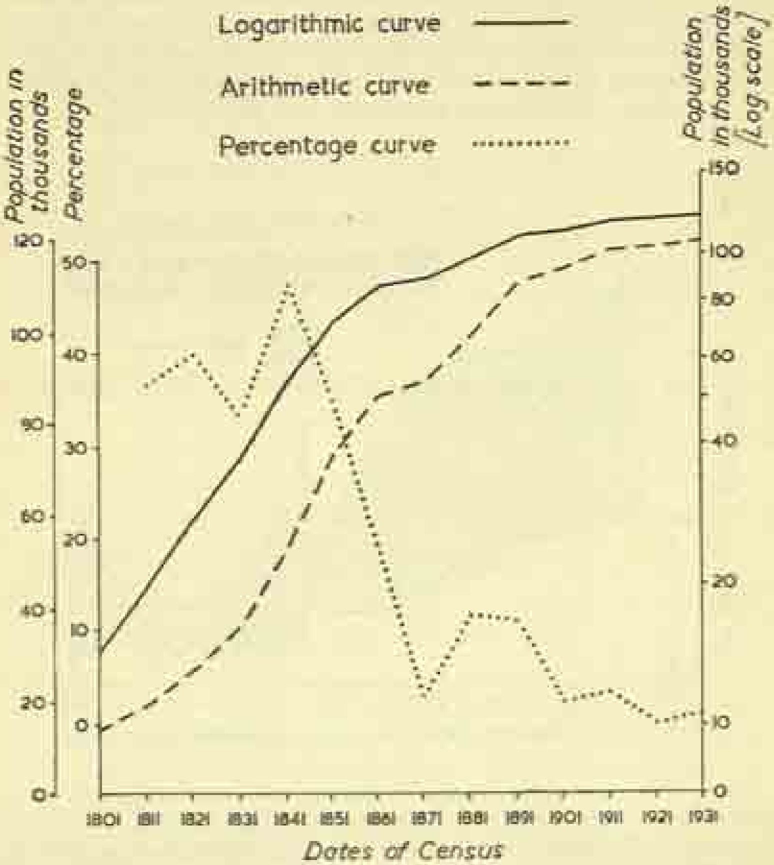


FIG. 172. VARIOUS LINE-GRAPHS OF POPULATION GROWTH

Source of data: *Census of England and Wales* (various dates).

The curves show the growth of the town of Preston in Lancashire in terms of the size of the population within its administrative boundary at the dates of the various censuses. Since the administrative boundaries have undergone certain changes, the curves do not necessarily reflect increases in population density.

T

Smoothed Curves

Where long-term trends in population growth or in fertility are being analysed, running means may be employed to smooth out curves (see p. 146). Curve-fitting is also occasionally used; the inherent problems are too complex to discuss here, and in any case, the number of occasions on which curve-fitting is a justifiable procedure are very few indeed.[1]

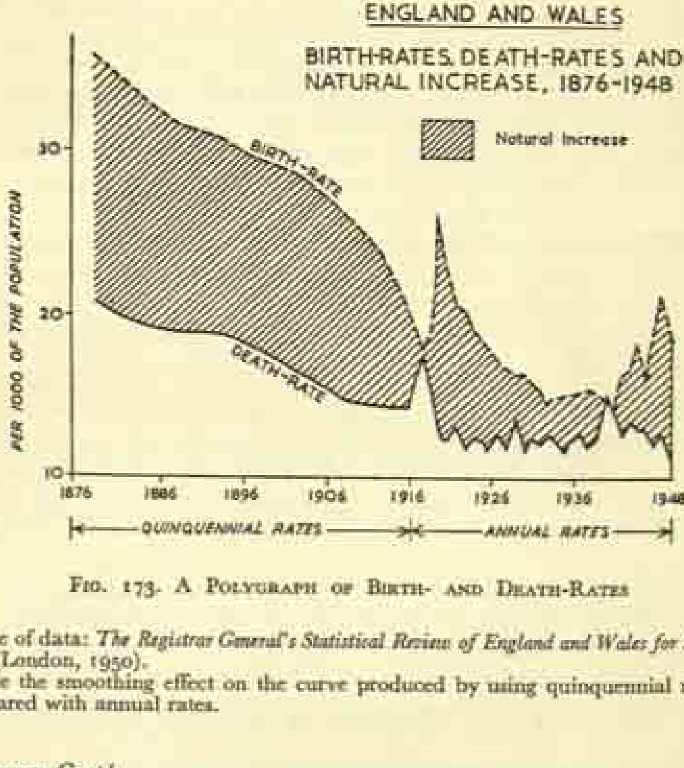


FIG. 173. A POLYGRAPH OF BIRTH- AND DEATH-RATES

Source of data: *The Registrar General's Statistical Review of England and Wales for the Year 1948* (London, 1950).

Note the smoothing effect on the curve produced by using quinquennial rates as compared with annual rates.

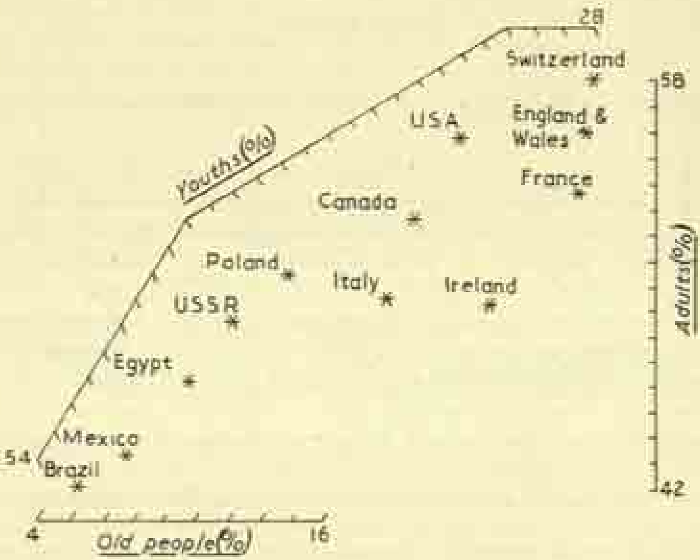
Frequency Graph.

These are used more particularly in analyses of changes in mortality and survival rates. For example, years of age from 0–100 may be plotted as abscissae, and the number of male or female survivors out of 10,000 as ordinates. Using this framework, data may then be plotted for a particular year, and points joined by a line to give a frequency curve. On the same framework other data may be plotted for

[1] See examples of curve-fitting in H. Gille (*op. cit.*).

other years and the points joined by lines pecked or dotted for clarity.[1]

Any other population data can, of course, be analysed on a frequency basis. Thus A. Stevens (*op. cit.*) made liberal use of frequency curves in his analysis of the rural population of Great Britain. Using the percentages of parishes and rural districts as ordinates, and mean



AGE-COMPOSITION OF DIFFERENT COUNTRIES

FIG. 174. A TRIANGULAR GRAPH OF AGE STRUCTURE

Based on P. Vincent 'Une interessante application du diagramme triangulaire', *Population*, vol. 2 (Paris, 1947). The critical ages have been taken as 20 and 60 years, and the graph refers to the year 1940.

densities per square mile as abscissae, he was able to establish modal densities of population for England and Wales and for Scotland.

Triangular Graphs

Triangular graphs are used where three variables in the composition of population require analysis. They are useful, for example, in the depiction of the young, the middle-aged and the old in any population. The percentage proportions of all three elements are first calculated; the percentage of the young is plotted along one axis of the

[1] See examples of these graphs in L. Henry and J. Voranger, 'La Situation Démographique', *Population*, vol. 5 (Paris, 1950).

triangular graph, of the middle-aged along another axis, and of the old along the third axis. Because the component values all add up to 100 per cent, all three values may be plotted on the graph by a single point. The position of this point within the triangle gives an immediate indication of the threefold age structure of the population. A number

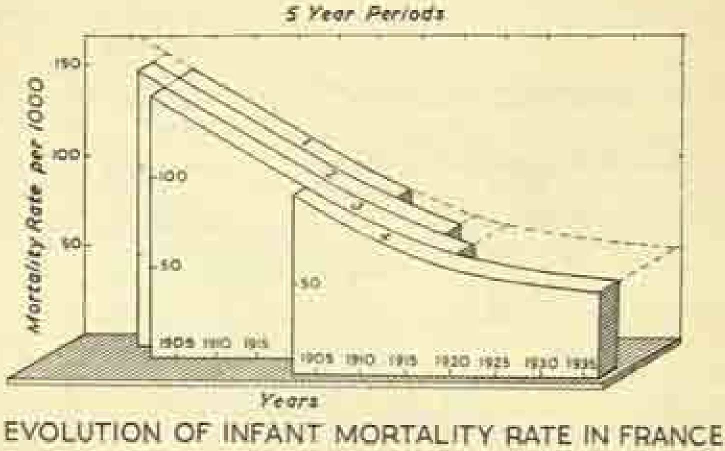


FIG. 175. A DEVICE FOR THE PROJECTING OF CURVES OF INFANT MORTALITY RATE

Based on J. Bourgeois, 'La situation démographique', *Population*, vol. 1 (Paris, 1946).
The four curves shown are contemporaneous and refer to conditions in four communes. The pecked line in the background represents the sum tendency of all four curves as arrived at by arranging the four curves in the manner indicated above.

of points plotted in the same triangle enables comparisons to be made between the age-structures of different populations (Fig. 174).

Projected Curves

A device for adjusting trend curves so that they might be compared is portrayed in Fig. 175. Comparisons of this kind prove useful when it is required to demonstrate that a particular trend which has existed in the past in one population, is true at the present time for another population. They are of help also in projecting curves into the future.

Semi-Logarithmic Scales

Graphs based on semi-logarithmic scales may be preferable for certain purposes to those in which arithmetic scales are employed.

Population Growth. If, for example, population growth is to be graphed, the time values are plotted as abscissae on an arithmetic scale, and

population values as ordinates on a logarithmic scale. The points are then joined. The resulting line gives not only an indication of total growth, but also a visual impression of rates of growth because the slope of the line is always proportional to the rate of growth (Fig. 172).[1]

Mortality and Survival Trends. Logarithmic scales are preferred to arithmetic scales when details of mortality and survival trends are being plotted, because fluctuations in the rates for the first year of life are very important and they can be clearly plotted on a logarithmic scale, whereas they tend to be compressed on an arithmetic scale.[2]

Deviational Graphs

Graphs which show deviations from average conditions help to elucidate regional variations in sex and age structure and in family structure. For example, percentage deviations from the national norm may be plotted in the form of a graph to give a picture of local variations in age and sex structure (Fig. 176). Local variations are plotted for quinquennial age groups, for males and females respectively, about a straight line which serves the dual function of representing national norms of male and female percentages. The graph then shows not only age variations, but also variations in the balance of the sexes from one region to another.[3] The method does successfully show important variations. For example, in Fig. 185 Lancashire as a whole does not differ greatly from the average figures for England and Wales, but in the case of Blackpool both males and females in the younger age-groups are very much under-represented; on the other hand, females in the older age-groups form a much larger element in the population than is normal in the country as a whole. The disproportion between the sexes is also much higher than average. Compare the population of Blackpool and that of Liverpool, where the balance of sexes is about normal but where younger age-groups have over-average representation.

Cumulative Graphs

The application of cumulative graphs to population studies might be exemplified with reference to the problem of population distribution.

[1] H. F. Dickie, 'The Use of Logarithmic Paper for Plotting Geographical Statistics', *Geography*, vol. 24 (London, 1939); and A. Davies, 'Logarithmic Analysis and Population Studies', *Geography*, vol. 33 (London, 1948).

[2] Semi-logarithmic scales are employed in graphs of specific death-rate trends, in E. Lenof, 'Mortality in New Zealand and England and Wales', *Population Studies*, vol. 3 (Cambridge, 1949–50).

[3] This graphical method is used by T. L. Smith (*op. cit.*), and he has devised the term 'Index Numbers of Population' to describe it.

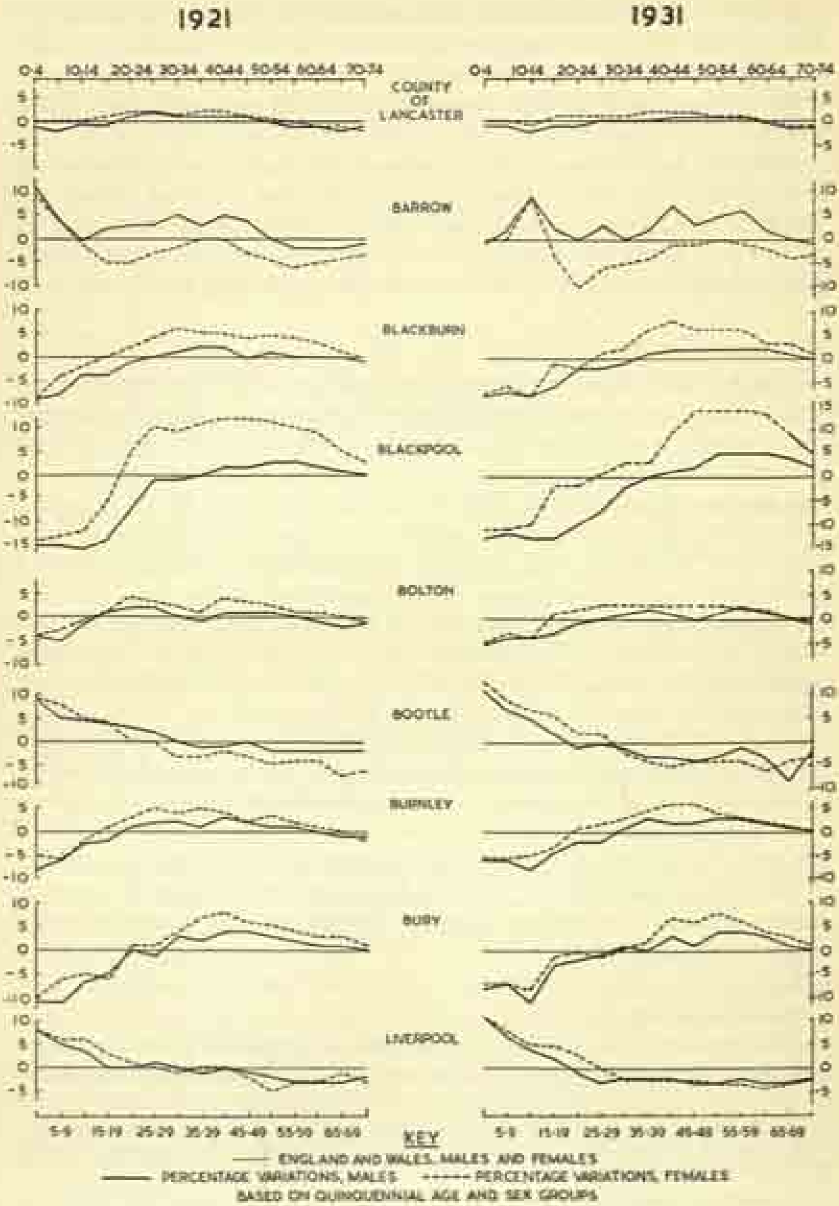


FIG. 176. DEVIATIONAL GRAPHS OF SEX AND AGE STRUCTURE

Source of data: *Census of England and Wales* (various dates).

Practically all the difficulties which face the cartographer in the drawing of population maps arise out of the great concentrations of population which occur in the cities and conurbations of the world. These concentrations themselves vary in size and statisticians have gone so far as to postulate a law of population concentration, the *Rank-Size Rule for Cities*.[1] Whether or not the law holds good in all

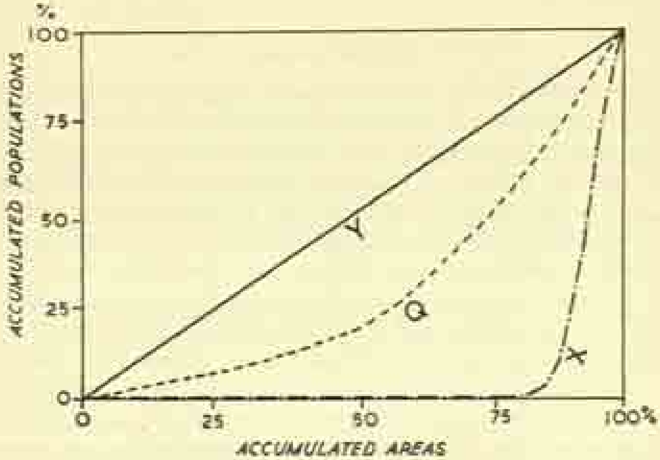


FIG. 177. THE PRINCIPLE OF THE CUMULATIVE GRAPH

cases, its application to the cities of the United States reveals useful evidence about concentrations of population in relation to area. These concentrations of population in any region may be demonstrated by means of cumulative graphs in which area is plotted against population.[2]

The administrative areas within the region, the cities, towns and rural districts, are first of all put in order of rank, according to the size of their populations. Areas and populations are then plotted cumulatively. If all the population lives in one place in five per cent of the total area of the region, the resultant curve would be an almost vertical line *X* (Fig. 177). If the population is spread out in a uniform manner, the resultant curve would be a straight line *Y*. The curve *Q* shows a population mostly concentrated in big cities but with a thin spread of rural population over the region as a whole. Cumulative

[1] G. K. Zipf, *National Unity and Disunity* (Bloomington, Ind., 1941). See also F. Auerbach, 'Das Gesetz der Bevölkerungskonzentration', *Petermann's Mitteilungen*, vol. 59 (Gotha, 1913).

[2] The computation of coefficients from such graphs is discussed by J. K. Wright, 'Some Measures of Distributions', *Annals of the Association of American Geographers*, vol. 27 (Lancaster, Pa., 1937). He applies his methods in 'Certain Changes in Population Distributions in the United States', *Geographical Review*, vol. 31 (New York, 1941).

graphs of this type may be used, not only to show the uniformity of the spread, i.e. the concentration of population within specific regions, but also the trends of population concentration over a number of years; they may be adopted also to express in quantitative terms the "degree of areal association of different distributions, i.e. the degree to which two distributions 'fit together' or tend to occupy different areas".[1]

Centrograms

Regional trends in the distribution of population can be graphed by means of *centrograms*. A number of points is plotted on a map which coincide as nearly as possible with the successive centres of gravity, or with the median points, of the population of a particular country as enumerated in decennial census returns. These points are then joined by a line which reflects any tendency of the centre of gravity, or of the median point, to shift from one decade to another. The centre of population is defined as a point upon which the country concerned "would balance if it were a rigid plane without weight and the population were distributed thereon, each individual being assumed to have equal weight and to exert an influence on the central point proportional to his distance from the point".[2] Where the median-point method is used, distance need not be taken into account. Needless to say, either calculation is laborious, but the results have significance for regional planning.[3]

[1] J. K. Wright, 'Some Measures of Distributions', *op. cit.*, p. 178.

[2] E. Raisz, *op. cit.*, p. 260.

[3] For elaborations on the technique, see E. E. Sviatlosky and W. C. Eells, 'The Centrographical Method and Regional Analysis', *Geographical Review*, vol. 27 (New York, 1937).

CHAPTER VI

MAPS AND DIAGRAMS OF SETTLEMENTS

Data

Distribution and Forms

There is a vast range of data which relates to the distribution of settlements and to their forms. As problems of distribution and forms of modern settlement are bound up with problems of origins, a historical as well as a geographical approach to settlement is imperative, and this immeasurably widens the scope of inquiry. Sources can be grouped into a number of categories.

Maps and Plans. Printed maps on a scale of 1:100,000 or larger invariably portray all settlements, either by conventional symbols, or by plan. For details of actual form, however, maps on a scale of about 1:25,000 or greater are necessary. In Britain the current One-inch and Six-inch series serve admirably to show distribution and form of settlements respectively. For field plotting, base-maps which give details of individual buildings must be used and plans on a scale of about 25 inches or even 50 inches to a mile are necessary.[1]

Past editions of topographical maps give some historical perspective. For example, the first editions of the British Ordnance Survey One-inch and Six-inch series are invaluable in the study of distributions during the first and succeeding decades of the nineteenth century. Tithe Award maps are also invaluable where available, as they supplement and sometimes pre-date the data given in Ordnance Survey maps. Often they are on a greater scale and give more detail of building plans, field boundaries and place-names, as well as throwing light upon conditions of tenure and land utilization.[2]

In addition to these, other map sources include old county maps,[3] printed town plans and manuscript maps of various kinds, in particular estate maps. The Land Utilisation Survey Maps of Britain must not be overlooked, because they contain information about total land taken up by settlements which cannot be found elsewhere. Geological maps, particularly drift-maps, give invaluable details about siting of settlement. The One-inch and Six-inch geological drift-maps

[1] The Ordnance Survey is preparing scale-plans of built-up areas (1:1,250 and 1:2,500) specifically for this purpose in connection with town-planning.

[2] Copies of Tithe Award maps are sometimes to be found in the local Parish Church. Copies and originals may be consulted at county record offices. See, for example, *Catalogue of Maps in the Essex Record Office, 1566–1855*, edited by F. G. Emmison (Chelmsford, 1947).

[3] See R. E. Dickinson's use of Saxton's maps in 'The Distribution and Functions of Smaller Urban Settlements of East Anglia', *Geography*, vol. 17 (London, 1932).

of Britain should be consulted wherever available. Unfortunately these maps are scarce to-day, but in cases of necessity the original manuscript survey maps may be viewed at the Geological Office.

Air Photographs. Air photographs provide the means of bringing settlement patterns up to date, and they are of basic value in the study of settlement where cadastral survey is lacking altogether. They are of use too for providing detailed supplementary information about settlements which does not appear on maps, for example, relationships of 'ridge and furrow' to settlement form, relationship of settlement to land-use and to land forms,[1] and evidence of former settlements.[2]

Documentary Sources. The origins of different forms of settlement are frequently bound up with obsolete conditions of land tenure, with former agricultural practices, with particular stages in the evolution of the economic structure of a region, with original field systems, with frontier functions, and so on. A particular form of settlement may be purely accidental or its site fortuitous. Only its history affords an explanation of the circumstances of its siting and form. The most important single document affording evidence about medieval settlement in Britain is the Domesday Book.[3]

Place-Names. Place-names are of paramount importance in the study of the origins of the distribution and of the spread, as well as of the character, of early settlements. Great care, however, must be exercised in the use of place-names. The random plotting of any place-names which happen to figure on ordinary topographical maps is to be deprecated, because many of the names plotted may not be genuine place-names. Fortunately, the English Place-Name Society has published a number of county volumes on English place-names, and they provide authentic lists of names.[4]

Archaeological Evidence. The reconstruction of the distribution and form of prehistoric settlements is dependent upon adequate archaeological evidence. This may be found in reports of excavation of settlements, for example, the excavation of Roman towns and of Iron Age hill forts. The general distribution of prehistoric settlement may often be inferred from plottings made of locations of archaeological finds. Cyril Fox's work still provides the best introduction to the general

[1] See the remarkable series of block diagrams illustrating settlement features, drawn directly from air photographs in T. Hagen, 'Wissenshaftliche Luftbild-Interpretation', *Geographica Helvetica*, vol. 5 (Bern, 1950).

[2] See for example the air photographs in W. G. Hoskins (ed.), *Studies in Leicestershire History* (Liverpool, 1950).

[3] This evidence has been systematically analysed by H. C. Darby, and some of the preliminary accounts have already been published, for example, 'The Domesday Geography of Norfolk and Suffolk', *Geographical Journal*, vol. 85 (London, 1935).

[4] E. Ekwall's *The Concise Oxford Dictionary of English Place-Names* (Oxford, 2nd edition, 1940) is a useful supplementary source. Before working with place-names, A. Mawer and F. M. Stenton, *Introduction to the Survey of English Place-Names* (Cambridge, 1924), should be read.

cartographical treatment of archaeological data as applied to settlement distributions.[1]

Structure of Settlements

The geographer is interested not only in the distribution and arrangement of settlements, but also in the functions which the settlements perform. Information about the functional structure may be gained from a number of sources.

Population Statistics. Details of the occupational and industrial structure of the population of different localities can be analysed to show the functional character of the settlements (see p. 260).

Building-Use and Urban Land-Use Surveys. Detailed information about the distribution of function in any settlement can only be obtained by making a survey of the uses to which the component buildings are put. Under the Ministry of Town and Country Planning Act, Local Authorities are obliged to make such surveys for themselves in connection with redevelopment plans, and occasionally information may be obtained from them. Surveys of this kind may be limited to the plotting of the use of the buildings themselves, or they may extend to the detailed plotting of land-use in built-up areas.

Directories. Apart from field observation, a great deal of information about settlement structure can be gleaned from local directories. Current editions of local directories and of the Telephone Trade Directory are useful, but just as important are earlier editions which constitute historical sources and give information about past conditions which often cannot be obtained elsewhere. Since settlement structure is dynamic, an historical approach is essential to the appreciation of changes and trends.

Inventories of Property. Inventories of property made by civic authorities or by estate agents and landlords contain useful supplementary data about building-use. A good example of such source material is the inventory of property in New York made by 'white collar' unemployed during the period of depression.[2]

Relationships of Settlements

Information about the relationships between various settlements is drawn from miscellaneous sources, but mention may be made of a few of the more important.

The network of communications as portrayed on topographical maps is an obvious reflection of relationships between settlements, but telephonic communications are not to be neglected in this connection (see p. 304).

[1] C. Fox, *The Personality of Britain*, 4th edition (Cardiff, 1943).

[2] See J. K. Wright, 'Diversity of New York City', *Geographical Review*, vol. 26 (New York, 1936).

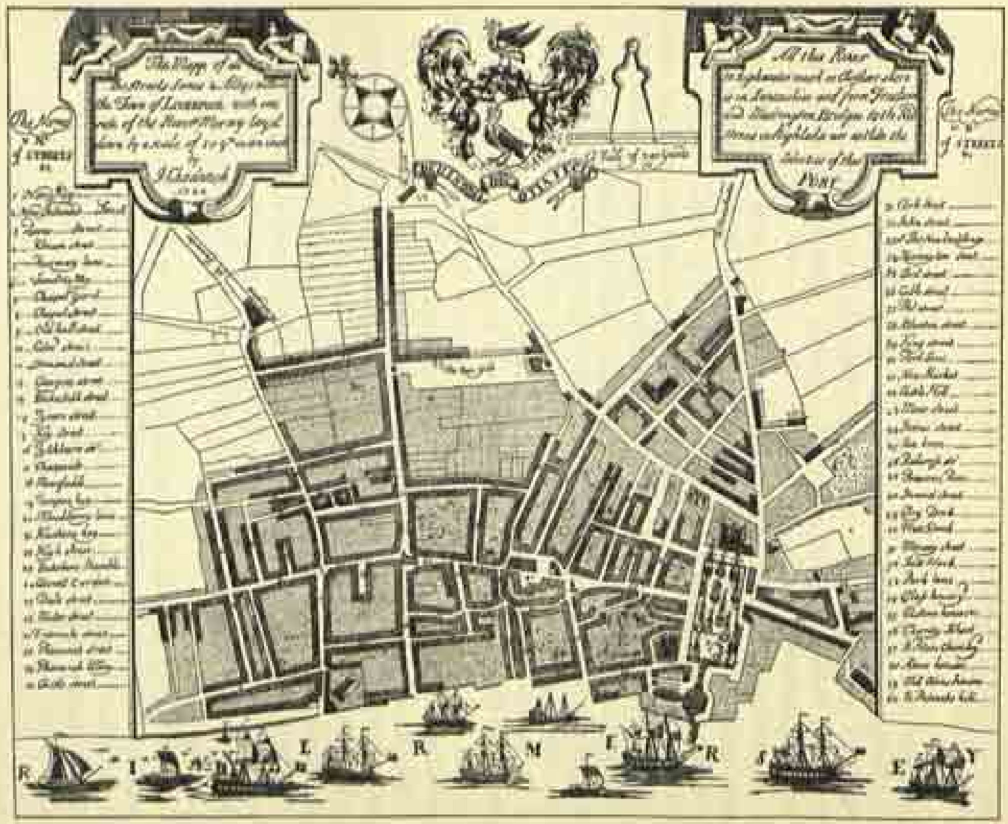


Fig. 178. A Facsimile Map of Liverpool.

The map has been redrawn and then reduced to less than one quarter of the scale of the original, i.e. from 21·75 inches to 5·0 inches in length. Details on the map may still be read with the aid of a magnifying glass.

Traffic Censuses. The communications' network gives no information about traffic density, but some indication is given in traffic censuses which are held from time to time, conducted by government agencies, or in the case of Britain, by the Automobile Association and the Royal Automobile Club.

Time-Tables. Apart from traffic censuses, local bus and train time-tables give information about density of traffic, although such time-tables are difficult to interpret.[1]

Population Statistics. Movement of population between settlements has obviously to be considered in the study of their relationships. Migration statistics have already been referred to (see p. 228). Just as significant is the information given in census returns about the daily movement of population between place of work and place of residence.[2]

Newspaper Circulation. Data about the area served by local newspapers are used in examining the relationships between small and large settlements, especially in the determination of the limits of urban fields.[3]

Details of Special Services. Details about settlements served by special centralized retailing establishments such as the local Co-operative Society, the local hospital, the local Defence Headquarters, are sometimes available to throw light on special problems of urban and rural relationships.

Market Areas. The size of and the area served by local markets reflect relationships between farming settlements and urban centres. Local Authorities often keep records of sales, and details concerning them may also be obtained from auctioneers' lists, etc.[4]

Questionnaires and Field-Work. Details about local shopping habits, about the extent of local hospital services, about local entertainment facilities and so on, are not easily come by, and some considerable field investigation is necessary before sufficient data can be assembled to allow aspects of the relationships between rural and urban settlements to be mapped. Questionnaires which are circulated via local organizations, such as women's clubs and schools, can be successfully utilized in this connection.[5]

[1] For details of the use of bus time-tables, see F. W. H. Green, 'Town and Country in Northern Ireland from a Study of Motor-bus Services', *Geography*, vol. 34 (London, 1949).

[2] The data are contained in the *Workplaces* volume of the Census of England and Wales, 1921 (H.M.S.O., 1925).

[3] J. P. Haughton, 'Irish Local Newspapers: A Geographical Study', *Irish Geography*, vol. 2 (Dublin, 1950).

[4] R. E. Dickinson, 'The Markets and Market Areas of East Anglia', *Economic Geography*, vol. 18 (Worcester, Mass., 1942).

[5] Relationships between Worcester and neighbouring villages were investigated by this method. See J. Glaisyer, *et al.*, *County Town* (London, 1946). A committee sponsored by the Geographical Association and under the chairmanship of A. E. Smailes is at present investigating 'urban fields' in Britain, and great use is being made of printed questionnaires. See also H. E. Bracey, *Social Provision in Rural Wiltshire* (London, 1952).

Facsimiles

Since the distribution of buildings is shown on topographical maps of various scales, as well as on plans and manuscript maps, it follows that settlement problems can be directly illustrated as facsimiles taken from such maps.[1] Moreover, facsimile reproductions have the advantage of authenticity (Fig. 178), particularly in the case of historical records.[2]

But although facsimile reproductions of maps are often used, it does not follow that facsimile reproductions are always either satisfactory or suitable. Facsimile maps are expensive because they may necessitate the use of colour or half-tones and attempts made to reproduce coloured maps in black and white are usually unsuccessful. More frequently reduction of scale is attempted with disastrous results as far as the legibility of the map is concerned.

Facsimiles which are intended for reduction should usually be redrawn (Fig. 178). Problems of scale and technique to be employed in the photographic reproduction of settlements from maps deserve careful consideration. A useful technique in the case of town plans is to superimpose a positive and a negative, emulsion to emulsion and slightly out of register. When printed the shadow effect so obtained creates an illusion of relief which adds to the clarity of the facsimile (Fig. 179).

Chorochromatic Maps

Chorochromatic maps can be used to show the regional distribution of various forms and types of settlement. They are of necessity generalized; areas with contrasting types of settlement, for example, are tinted to show major variations, or delimiting lines between settlement types are drawn and the areas so delimited labelled accordingly.[3]

Instead of tints or shading, symbols may be employed to show distributions. Maps of this type are sometimes termed *choroschematic*. They have the advantage in the case of settlement of showing admixture of types (Fig. 180).

Maps of this type employing pictorial symbols are used to portray

[1] There are many examples of this. A. Demangeon's maps based on the French 1:10,000 series might be cited in 'Types de peuplement rural en France', *Annales de Géographie*, vol. 48 (Paris, 1939). Facsimiles of the Six-inch series are to be found in H. Thorpe, 'Some Aspects of Rural Settlement in County Durham', *Geography*, vol. 35 (London, 1950). Numerous facsimiles to illustrate settlement problems are reproduced in M. A. Lefèvre, *Principes et Problèmes de Géographie Humaine* (Brussels, 1946).

[2] M. A. Lefèvre, *op. cit.*, for example, makes use of facsimiles from J. de Deventer, *Atlas des Villes de la Belge au XVI^e Siècle*, to illustrate aspects of the morphology of towns.

[3] See an example in M. A. Lefèvre, *op. cit.*

FIG. 179. A PHOTO-FACSIMILE

Based on *Atlas topographique de la Suisse (Atlas Siegfried)*, 1:25,000, sheet no. 451 (Berne, 1934).

This half-tone shows part of the town of Geneva, but has been produced in such a way as to emphasize the plan of the town.

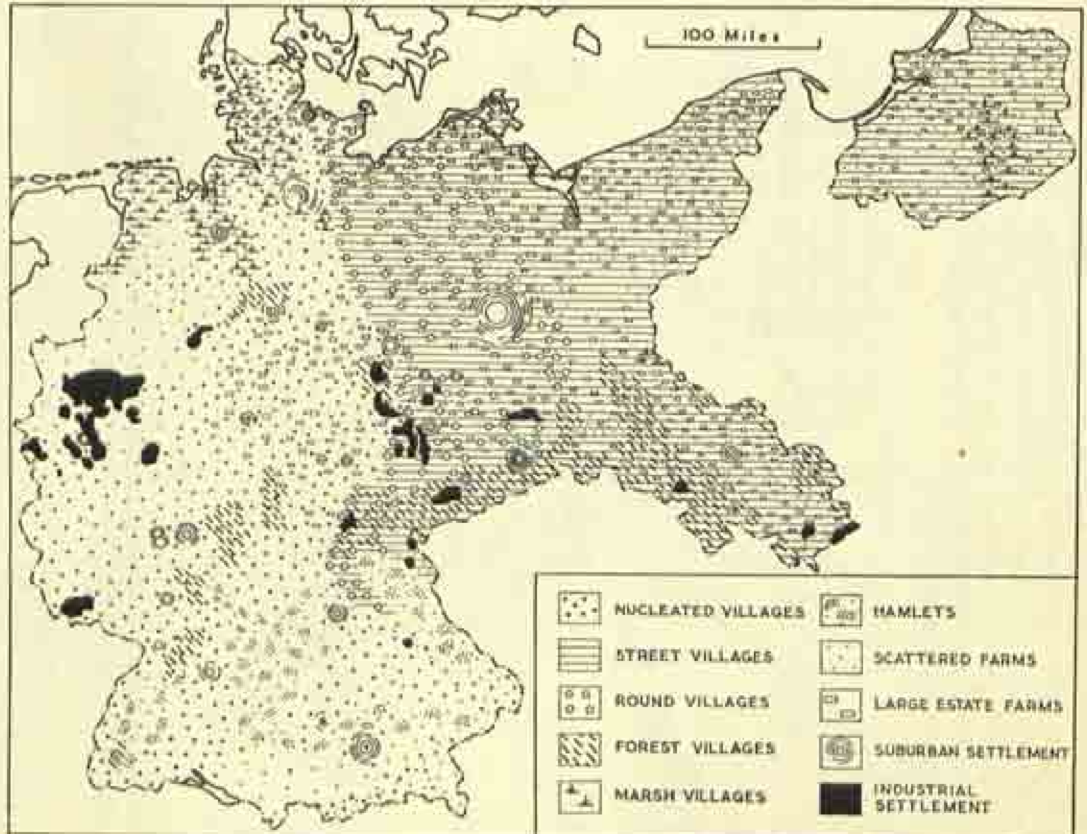


FIG. 180. A CHOROSCHEMATIC MAP OF SETTLEMENT

Based partly on maps in (1) *E. von Seydlitzsche Geographie*, vol. 4, 'Mitteleuropa' (second edition, Breslau, 1930); (2) R.E. Dickinson, 'Rural Settlements in the German Lands', *Annals of the Association of American Geographers*, vol. 39, p. 260 (Lancaster, Pa., 1949).

the distribution of house-types and forms of buildings. For example, the distributions of closed and open farm-buildings, of stone, wattle, and timber houses, of roof-type, may be suitably depicted by symbols; very often pictorial symbols are most effective to convey regional variations in the plan or elevation of buildings, or to convey variations in the building materials used.

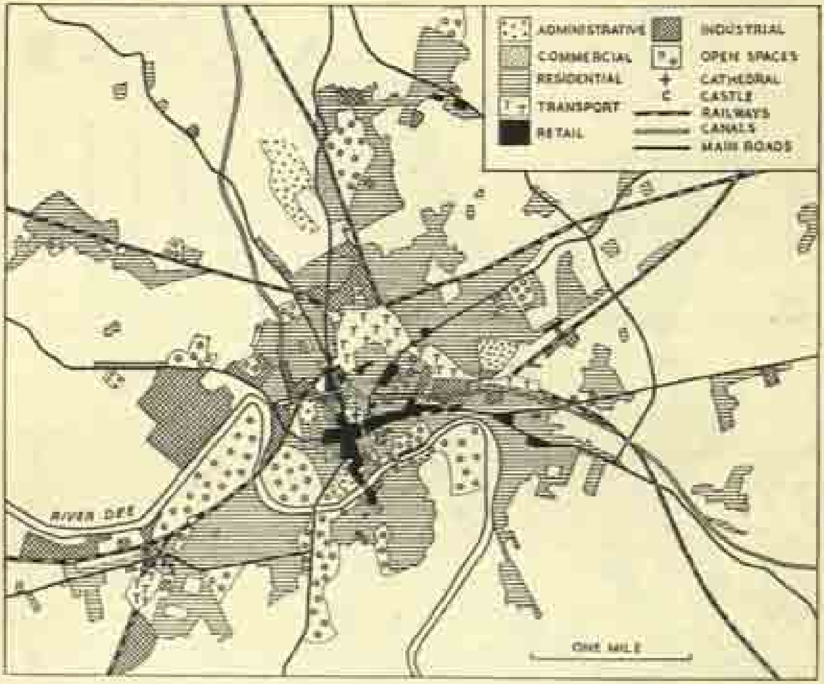


FIG. 181. A CHOROCHROMATIC MAP OF URBAN LAND USE

The map relates to conditions in the county town of Chester in 1949. Land used for agricultural purposes has been left unshaded. Data were derived from field surveys.

The chorochromatic technique has a special application in the illustration of the differentiation of urban land-use (Fig. 181). These maps are of particular value to the town-planner. They are usually executed in colour and are compiled from field surveys.

TRACES

It is often unnecessary to reproduce facsimile all the detail of specific maps when settlement patterns are being considered. Indeed, the very process of selecting only certain items on the map and extracting them

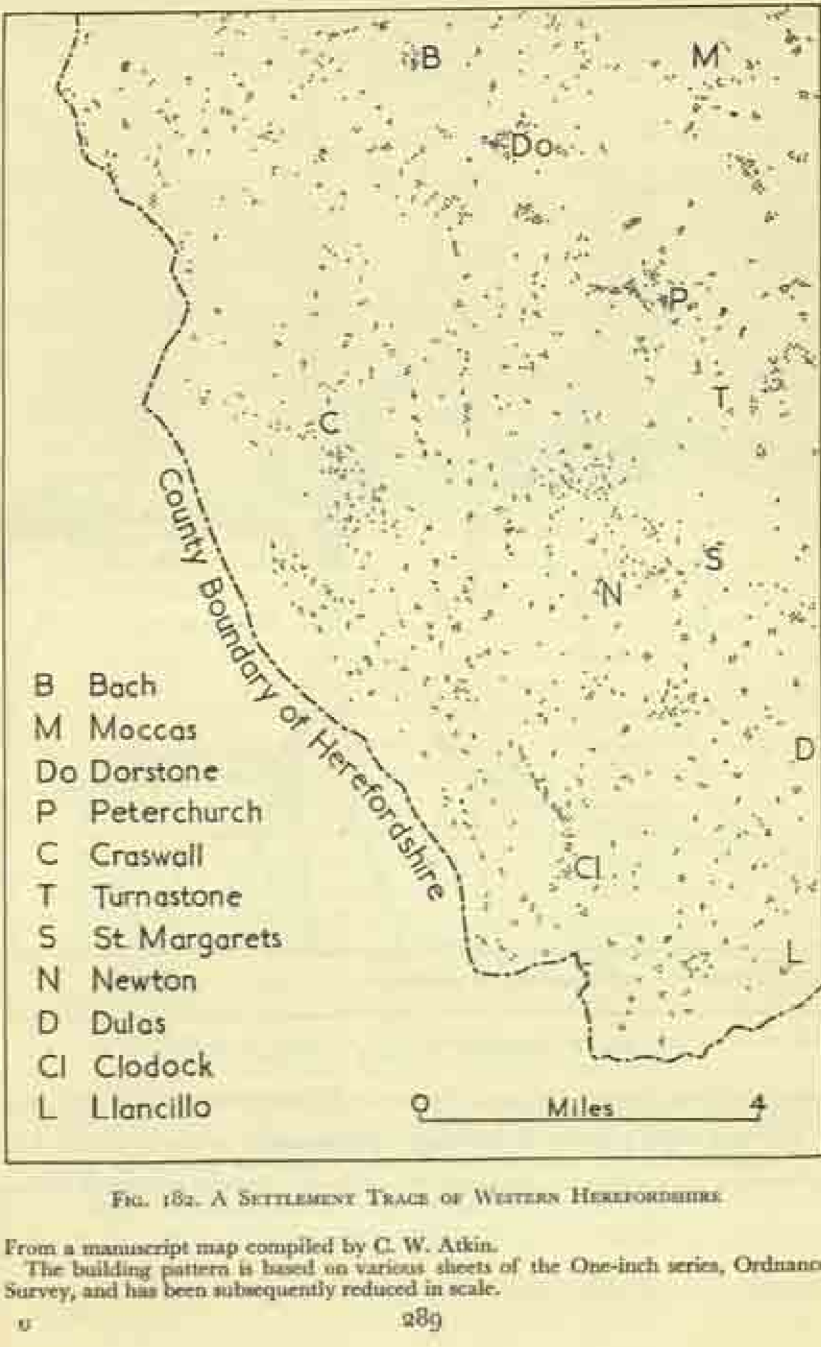


FIG. 182. A SETTLEMENT TRACE OF WESTERN HEREFORDSHIRE

From a manuscript map compiled by C. W. Atkin.

The building pattern is based on various sheets of the One-inch series, Ordnance Survey, and has been subsequently reduced in scale.

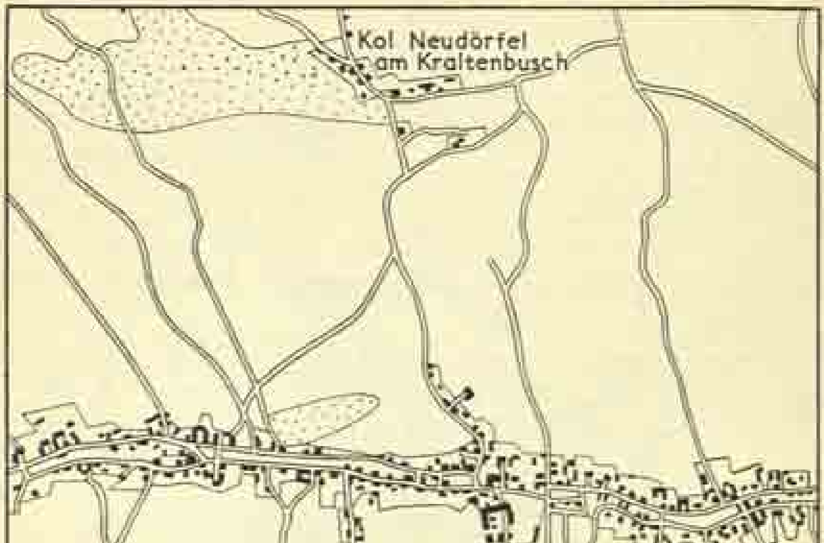


FIG. 183. A SELECTIVE TRACE OF A GERMAN VILLAGE

Based on *Preuss. Masstisch-blatt*, 3012, *Freiburg (in Niederschlesien)* 1:25,000 series, and after G. Braun, *Deutschland* (Berlin, 1936).

The map shows a typical 'forest-village' (*Waldhufendorf*) in Lower Silesia. Just sufficient detail has been extracted from the map to show the form of the village, its relationship to remaining woodland, and the pattern of communications which reflects the systematic exploitation of woodland resources on either side of the village.

for reproduction purposes by means of a trace may aid analysis by shifting the emphasis from the total map to certain distributions.

Building Patterns

The extraction of the building pattern to the exclusion of all other topographical detail serves to clarify the arrangement of the buildings, and significant features of their arrangement may more easily be noted. The extraction is readily accomplished by tracing off all buildings and marking them black (Fig. 182). Alternatively, it may be useful for certain purposes to trace all the area taken up by buildings, including gardens, industrial yards and installations of various kinds. In the case of British settlement, this can be accomplished by tracing off the Land Utilisation Survey maps all land marked in red and purple, and marking such areas black on the trace.[1] The procedure has special merit in that reduction of the tracings can be effected without great loss of detail, but it does not serve always to show the forms of the settlements.

The subsequent analysis of the causes and nature of regional differences in the settlement pattern may be aided if specific topographical features are added to the trace, in addition to the building pattern. The inclusion of the road pattern may, for example, elucidate ribbon development, or it may help to explain forms of rural settlement such as the street-villages of northern Belgium,[2] the forest-villages of northern Germany (Fig. 183), and the round-villages of eastern Germany. Certain types of rural settlement, moreover, may themselves be associated with distinctive road patterns (Fig. 184). In the case of towns, the pattern of roads is often the most conservative feature of urban morphology. A tracing of the road pattern of a town may be sufficient to show details of its origin and form without the added labour of tracing the numerous buildings of the town. It must not be forgotten, either, that railways constitute an important feature in the structure of towns, and the tracing of the railway pattern has value in this connection.[3]

Forms of settlement in certain parts of the world have had their origin in relation to various field systems. Hence the inclusion of field boundaries may sometimes help to illustrate the conditions of origin of particular settlements (Fig. 185). Enclosures have, of course, greatly modified British field systems over a long period of years. Traces from

[1] Plenty of examples of this technique may be seen in the various volumes of the *Land Utilisation Survey of Britain*.

[2] M. A. Lefèvre, *L'Habitat rural en Belgique. Etude de Géographie Humaine* (Liége, 1926).

[3] See maps in S. H. Beaver, 'Railways of Great Cities', *Geography*, vol. 22 (London, 1937).

enclosure maps and old estate maps provide useful evidence where enclosure of land has taken place relatively recently.[1]

The addition of parish, commune or township boundaries in the case of rural settlement and of administrative boundaries in the case of towns, may be necessary to clarify certain aspects of the distribution of settlements. Thus the addition of parish boundaries, for example, serves to show the siting of villages in relation to the resources of the parish. The parish is not always a unit of settlement in the British Isles, but where there is reason to believe that the parish boundaries do, or once did, delimit one parish economically from another, then obviously these boundaries become significant features.

Natural vegetation, particularly the prevalence of marsh, heathland and forest, often affects forms of regional settlement. For example, the forest-villages of Silesia and the marsh-villages of the coastlands of Northern Europe, are related to the colonization and exploitation of different types of natural environment. Consequently, the inclusion of details of natural vegetation and of land-utilization may add considerably to an understanding of the settlement forms (Fig. 183).[2]

Tracings from geological maps, both solid and drift, help to illustrate the location of villages. The distribution of spring-line villages, or villages on drift-free sites, is best explained by references to geological maps. Moreover, geological distributions may exert some influence, directly or indirectly, on the form of villages. The lineal agglomerations in the valleys of the chalklands of Dorset differ considerably in form from the dispersed settlements of the neighbouring claylands of the Vale of Blackmoor. P. L. Michotte's maps of Belgium which show the distribution of settlements upon geological base-maps might be cited as a good example of this type of illustration.[3] These maps are coloured to show geological distributions, and settlements are shown by enlarged and clarified symbols.

Significant geological distributions may often be shown by outlines and by stipples, providing that such details do not obscure the settlement symbols.

The siting and form of settlements may be related to land-forms. Land-forms as reflected in the pattern of drainage and relief may therefore be depicted to show specific relationships. Meander-site

[1] See the fine selection of maps in M. Bloch, *Les Caractères Originaux de l'Histoire Rurale Française* (Oslo, London, etc., 1931); also M. A. Davies, 'Selected Types of Settlements and Field Shapes in Pembrokeshire', *Land Utilisation Survey of Britain*, Pt. 32 (London, 1939).

[2] For further examples, see E. H. G. Dobby, 'Settlement Patterns in Malaya', *Geographical Review*, vol. 32 (New York, 1942); and K. C. Edwards, *et al.*, 'The Nowy Targ Basin of the Polish Tatra', *Scottish Geographical Magazine*, vol. 51 (Edinburgh, 1935).

[3] P. L. Michotte, *Belgique. Echantillons-types de Régions Géographiques*. Collection Jean Brunhes, 1:20,000 (Paris, various dates).

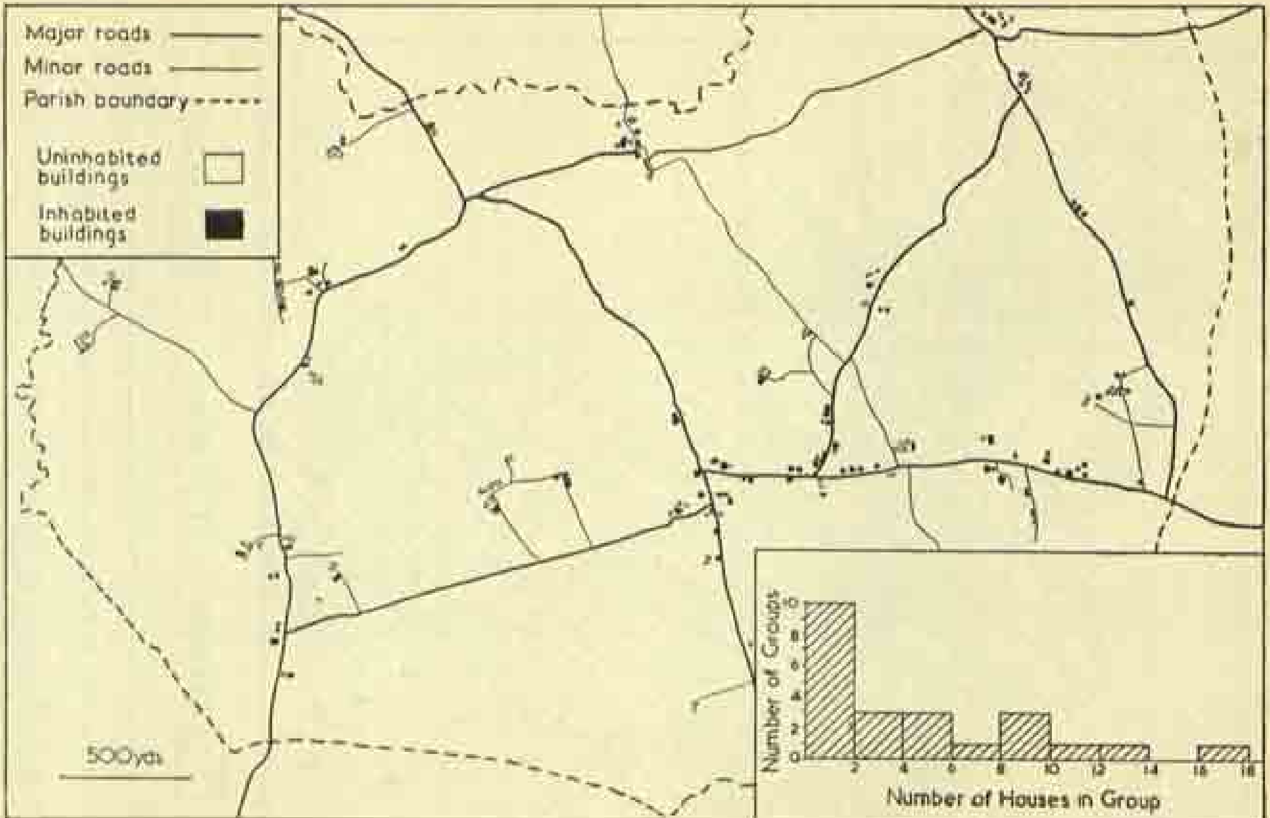


FIG. 184. A SELECTIVE TRACE OF HOLWELL, A DISPERSED VILLAGE IN THE VALE OF BLACKMORE

The inset illustrates a method of analysing the house-groupings in the parish.

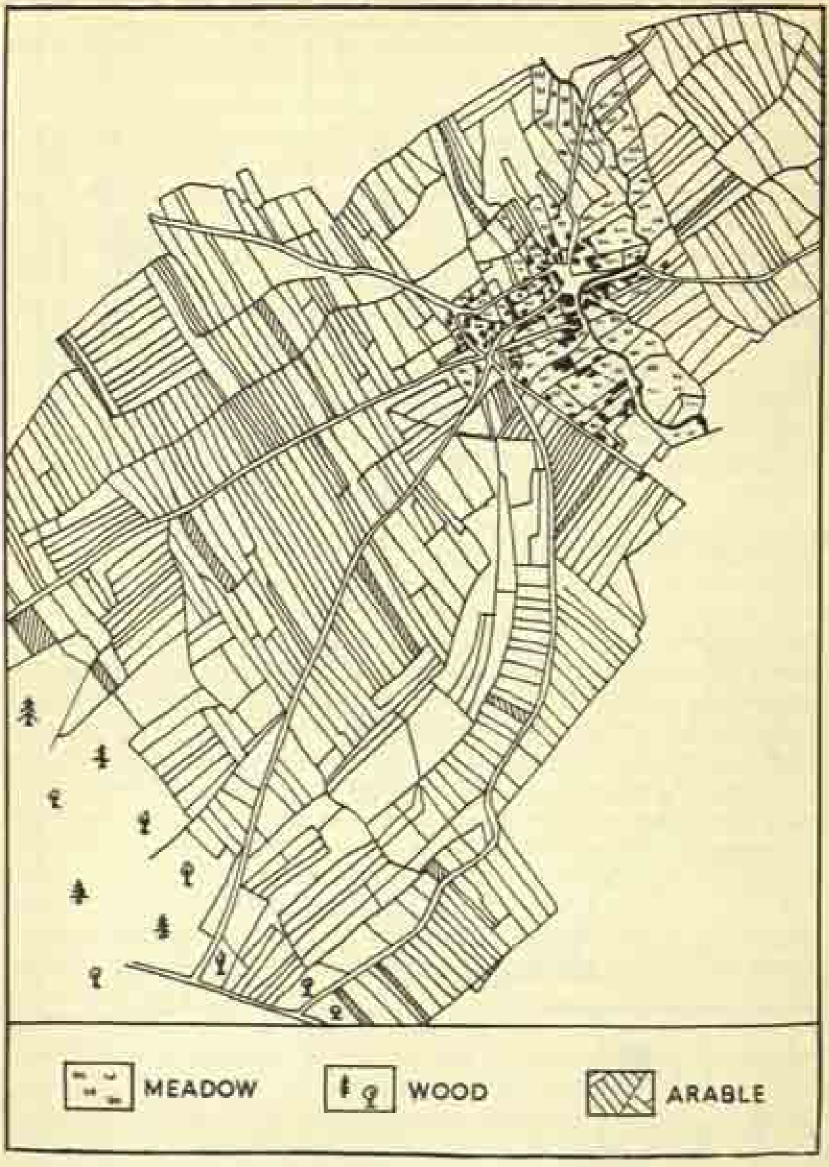


FIG. 185. A TRACE OF A VILLAGE WITH FIELD BOUNDARIES

Based on S. Ilešič, 'Vasi na Ljubljanskem polju in njegovem obrobu', *Geografski Vestnik*, vol. 10 (Ljubljana, 1934).

The village is Spodnje Brnik in Slovenia, a typical *Gewanndorf*. Individual field boundaries are shown, and strips belonging to one farm have been shaded to indicate the extent of the fragmentation of holdings.

towns, for example, settlements on river terraces, gap towns, towns defensively placed on isolated hills, and dry-valley settlements, are all instances of such relationships. Usually the tracing of certain contour-lines and drainage channels suffices to summarize particular land-forms. Hachures, it might be noted, are frequently more helpful than contours in demonstrating certain aspects of site.

Elements of the Settlement Pattern

So far the settlement pattern has been considered without reference to the various kinds of buildings and installations which make up the pattern. The buildings may be of different ages, they may perform different functions, they may vary architecturally one from another. Except for the information given by place-names, not much attempt is made in topographical maps to differentiate between the variety of elements in the building pattern. Symbols are used to show churches, and in the case of the Swedish 1:100,000 series, individual farms are differentiated by symbols.[1] Different housing patterns are also shown symbolically in specific editions of the British One-inch series,[2] and much can be inferred about the residential character of different neighbourhoods by an inspection of the building patterns given on maps.

For a proper analysis of the elements in the building patterns, however, a certain amount of field work is necessary. Elements in the building pattern which might come in for special study are age elements, architectural elements, for example, height of buildings[3] or style, and functional elements. The treatment of age elements proffers certain problems in the selection of dates to delimit age categories which are to have significance; inquiry into the architectural elements may prove of use in the demonstration of the changing functions of buildings, and in the reconstruction of historical functions performed by a particular settlement. It is not intended to consider age or architectural analysis here, but something further may be added about functional analysis.

Functional Elements. Mention has already been made of building-use surveys (see p. 283). Such surveys provide the data for functional analyses of settlement pattern. The essence of the cartographical treatment is to produce distribution maps of the functional elements. This may be achieved by tracing the settlement pattern in detail and tinting individual buildings and installations according to the nature of

[1] For maps of distribution of farms extracted from the Swedish topographical maps see H. W. Ahlmann, 'The Study of Settlements', *Geographical Review*, vol. 18 (New York, 1928).

[2] See H. Rees, 'The Representation of the Housing Patterns in Fifth and Sixth Editions of the Ordnance Survey One-inch', *Geography*, vol. 31 (London, 1946).

[3] See W. W. Atwood, 'A Geographical Study of the Mese Verde', *Annals of the Association of American Geographers*, vol. 1 (Lancaster, Pa., 1910).

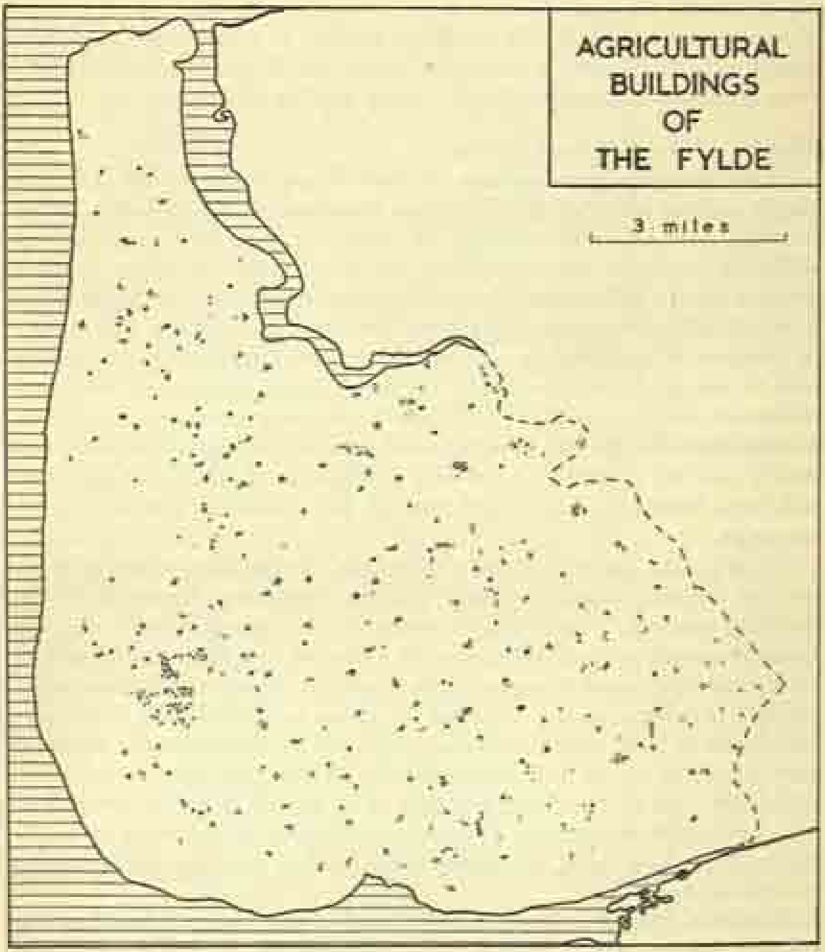


FIG. 186. A TRACE OF FARM-BUILDINGS IN THE FYLDE

Based on field reconnaissance with Six-inch series, Ordnance Survey maps. Glass-houses are indicated by open symbols, and farm-buildings by solid black symbols. All symbols have been exaggerated for the sake of clarity.

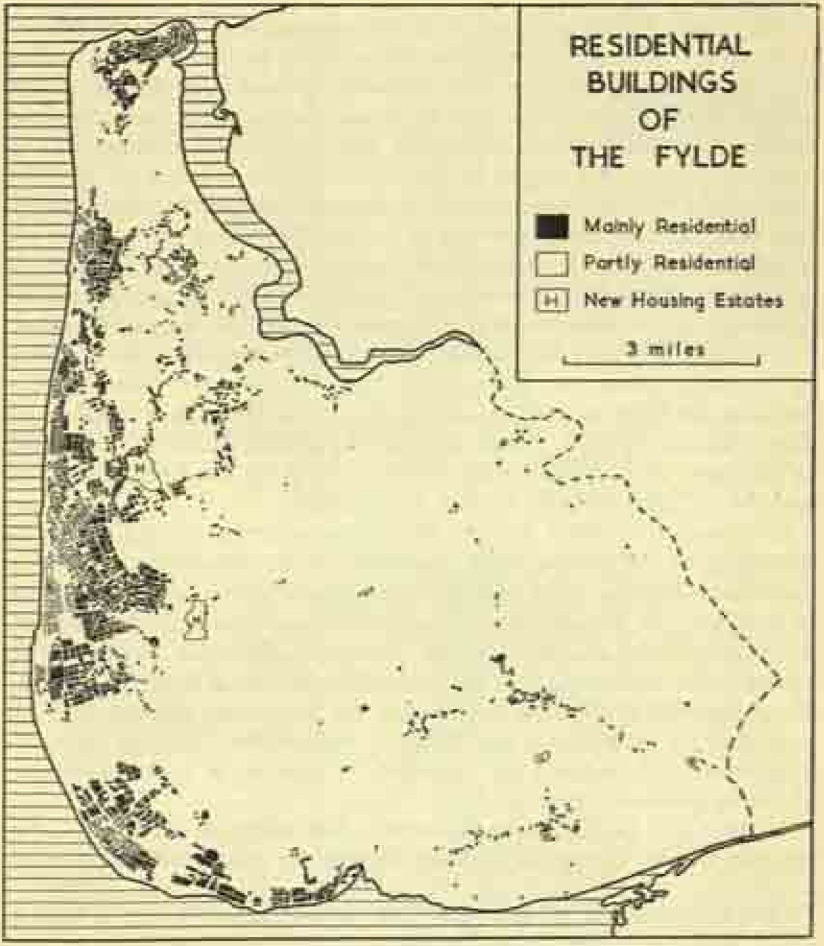


FIG. 187. A TRACE OF RESIDENTIAL BUILDINGS IN THE FYLDE

Based on field reconnaissance with Six-inch series, Ordnance Survey maps. For the purpose of this map, farm-buildings have not been included as residences.

their functions, or as a more practicable method, particular elements may be extracted from the pattern and considered separately (Figs. 186–7).

The fundamental problem is to show functional elements over a wide area, without over-reducing the tracing so that isolated buildings are lost in the process. The following method is applicable in the case of dispersed buildings such as farms. Suppose, for example, it is required to show the distribution of the agricultural element in the building pattern of a region in Britain. The data is compiled by field survey on a Six-inch base-map. The symbols representing farm buildings may then be transferred on to a 1:25,000 base-map, or even on to a One-inch map, providing that care is taken to locate the symbols accurately (Fig. 186). This method cannot be used for agglomerated buildings, but in this case the problems of reduction are not so acute.

A further difficulty in mapping functional elements in the building pattern arises from the necessity of deciding upon the function of a building used for more than one purpose. In Fig. 187 a solution to this problem is offered. The proportion of a specific function, residential in this case, performed by each block of buildings has been estimated, and the building symbols shaded accordingly.

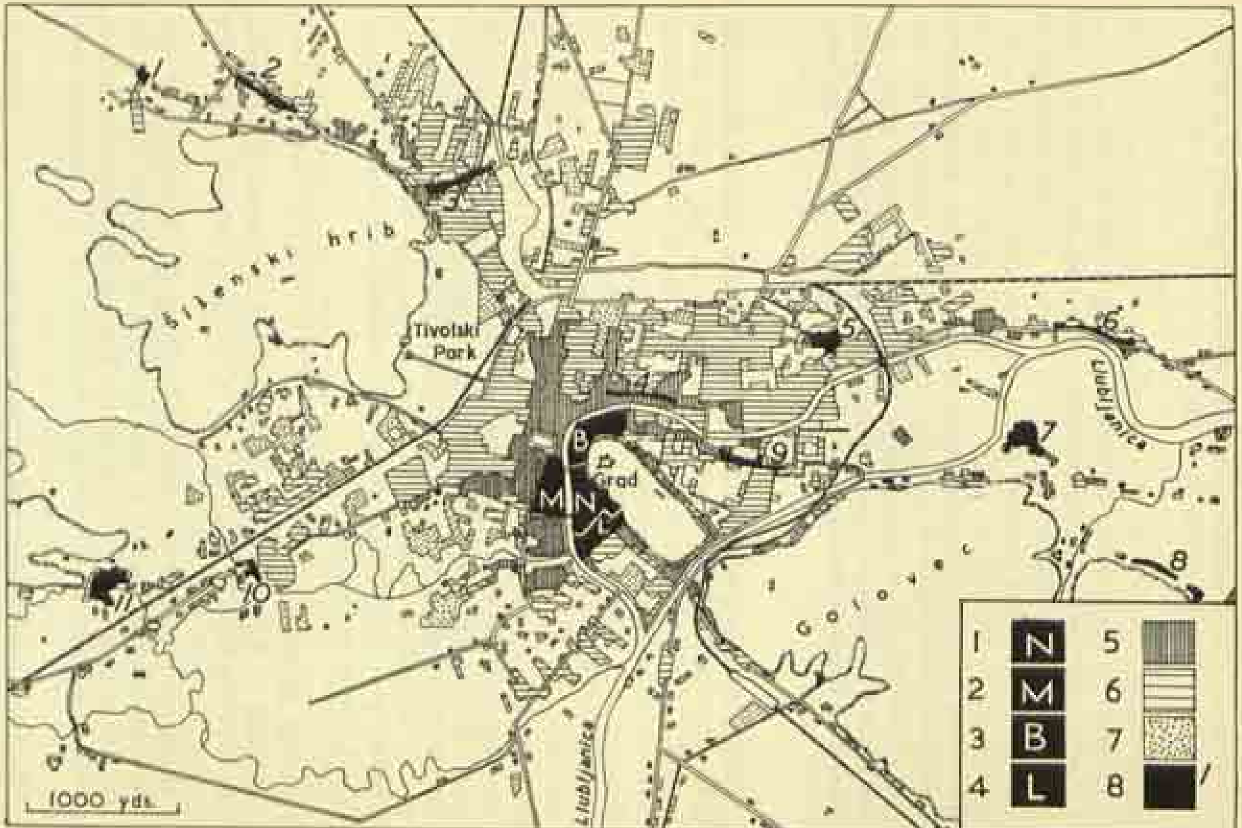
Elemental functional analysis of settlement pattern facilitates consideration of the factors both determining the distribution of settlements and the form of the settlement pattern. It is often a useful exercise to compare the arrangements of a particular element in the pattern, for example, the central business district, in different towns,[1] or to compare the arrangement of agricultural buildings in different regions. The principles of plotting elements in the settlement pattern may be extended by considering the detailed composition of each element. The residential element, for example, is capable of subdivision into various grades of property.

It must not be forgotten, however, that settlement pattern is an organic whole. Elemental analysis should be employed as much to

[1] See, for example, G. W. Hartmann, 'The Central Business District: A Study in Urban Geography', *Economic Geography*, vol. 26 (Worcester, Mass., 1950).

FIG. 188. A GROWTH MAP OF LJUBLJANA

Based on A. Melik, 'Razvoj Ljubljane', *Geografski Vestnik*, vols. 5–6 (Ljubljana, 1930).
The references in the key are as follows: **1**. the medieval nucleus; **2**. the new market built in the 13th century; **3**. the town on the edges of Mestni street and around the bishop's palace, built at the beginning of the 14th century and later; **4**. the manorial quarter attached to the town in 1533; **5**. the growth of the town up to 1825; **6**. growth to 1914; **7**. growth to 1929; **8**. original nuclei of surrounding rural settlements, consecutively numbered.


Šišenski hrib
Tivolski Park
Grad
Ljubljanica
Golovec
1000 yds.
1 N
2 M
3 B
4 L
5
6
7
8

demonstrate the relationships between its various points, as to analyse the variety of ingredients in its make-up.

Growth Maps

Mention has been made of date-of-building traces. Such traces give a rough guide to the growth of particular settlement units, but they are not always completely satisfactory in this respect. Often much rebuilding has taken place in the centre of a town, the age of which is no guide to the growth of the town from a specific nucleus. With the aid of a series of topographical maps, composite traces may be constructed which provide a truer picture of the expansion of the town and of the rate of its growth (Fig. 188). One-inch maps which give the limits of built-up areas are usually sufficiently detailed to plot growth by means of tracing the building pattern at successive decades.

Symbols

Strictly speaking, even the tracing of settlement patterns from topographical maps, which is referred to above (p. 291), makes use of symbolic illustration, insomuch as the settlements on topographical maps are sometimes conventionally depicted because of scale problems. However, the symbols on these maps usually reflect the plan of the original buildings where possible. The symbols dealt with in this section take the form of dots, proportional circles, or differentiated unquantitative symbols such as stars and squares. These symbols are used generally to depict the distribution of settlements over a wide area, where traces would be impracticable, to depict elements within the settlement pattern, to indicate different functions of settlements and of individual buildings, to relate settlements to population, to illustrate problems of siting, form and structure, and to show relationships between settlements.

Individual Buildings

Symbols to show individual buildings have their uses. The distribution of habitations, or of farms, can be shown by dot maps where one dot is equivalent to one unit.[1]

Differential symbols are useful for depicting the distribution of individual buildings according to their function, in order to illustrate the plan and structure of rural settlements. The dots may represent houses, churches, schools or administrative buildings. G. T. Trewartha used this method to demonstrate varieties of hamlets in the United States.[2]

[1] See Edgar Kant, *Quelques Problèmes Concernant la Représentation de la Densité des Habitations Rurales*, p. 455. *Apophoreta Tartuensia* (Stockholm, 1949).

[2] G. T. Trewartha, 'The Unincorporated Hamlet', *Annals of the Association of American Geographers*, vol. 33 (Lancaster, Pa., 1943).

Urban Structure. Symbols are frequently employed to show the distribution of offices, industrial undertakings, shops and banks in towns (Fig. 189). Spheres proportional in size to the number of employees in a firm enable important differences in the size of undertakings to be depicted.[1] Factory locations may be plotted according to the number of hands they employ or according to the amount of capital invested in them.[2]

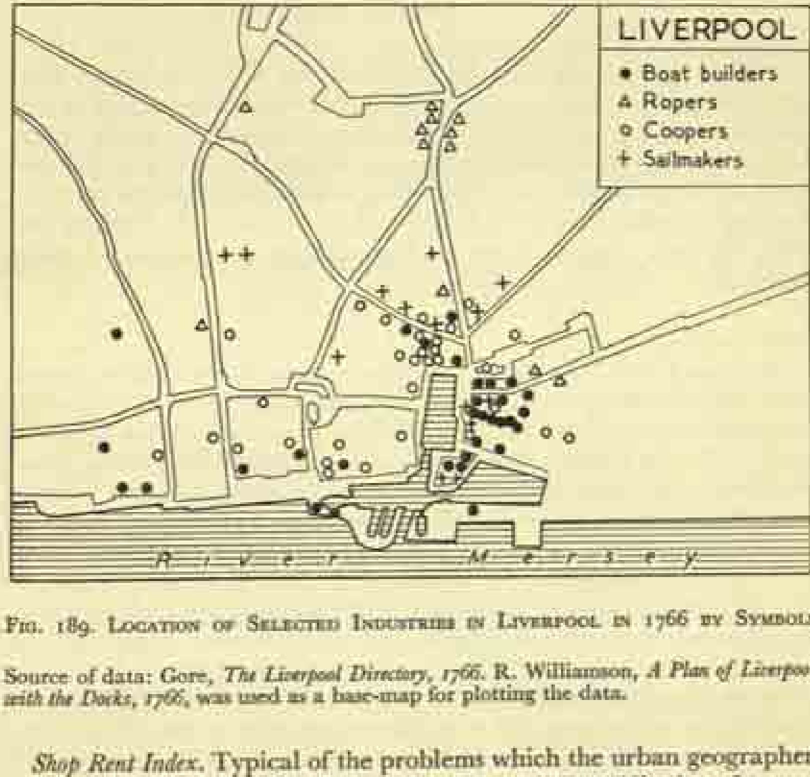


FIG. 189. LOCATION OF SELECTED INDUSTRIES IN LIVERPOOL IN 1766 BY SYMBOLS

Source of data: Gore, *The Liverpool Directory, 1766.* R. Williamson, *A Plan of Liverpool with the Docks, 1766,* was used as a base-map for plotting the data.

Shop Rent Index. Typical of the problems which the urban geographer encounters in his mapping of town structure is the difficulty of representing the distribution of the intensity of shopping within a particular town. Proportional symbols have to be devised because dot maps to show the distribution of shops do not reveal shopping intensity. Data on which to base the symbols are hard to come by. Annual turnover is often inaccessible, the size of window is not a reliable guide, and

[1] Aspects of the urban structure are shown by these methods in the analysis of Stockholm, by W. William-Olsen and others, of which a summary is given in 'Stockholm', *Geographical Review*, vol. 30 (New York, 1940).

[2] J. E. Orchard, 'Shanghai', *Geographical Review*, vol. 26 (New York, 1936).

rents vary according to the size of the buildings. Even the number of employees is misleading because of the different values of goods handled by particular shops. In his analysis of Stockholm, Olssen offered one solution of the problem. He devised a shop rent index which took into account the total shop frontage in a particular street, together with the rents paid by individual shops. He suggested the following formula:

$$\textit{Shop Rent Index} = \frac{\textit{Total Shop Rents in the Street Frontage}}{\textit{Length of Street Frontage}}$$

The shop rent index is thus the shop rent per unit of frontage. Proportional symbols can be constructed on the basis of these data in the form of rectangles, the depth of which vary according to the index (Fig. 190). The rectangles may then be shaded according to the different activities of the shops. These maps may be simplified to show shopping intensity road by road throughout the town, by making the width of each road conform to the varying proportions of shop front index.

Town and Village Symbols

Population Totals. The convention of representing the distribution of towns and villages by dots, small circles, small squares, dots in squares and similar symbols has a wide application. These symbols are designed to show the importance of each town as measured by the size of its population, according to the totals enumerated within the civic boundaries. These totals may not be fully representative of a town's regional importance, because the built-up limits of towns are not coincident with the civic administrative boundaries. Too often, also, a purely arbitrary classification of population totals is employed, such as towns with a population over one million, over 100,000, over 50,000 or over 10,000 inhabitants.[1]

Certain significant population totals can serve to indicate the function of particular settlements and to point to their place in the urban hierarchy. For example, a study of settlements in the United States suggests that purely rural centres usually have a population of about 25–300 and that market centres performing certain urban functions have a population of about 400–4,000. Probably one of the most controversial studies of the theory of the definition and distribution of urban centres

[1] Sometimes a useful purpose is served by mapping towns according to a progressive classification of population totals. An outstanding example of the application of such a method is to be found in M. Jefferson, 'Some Considerations of the Geographical Provinces of the United States', *Annals of the Association of American Geographers*, vol. 7 (Lancaster, Pa., 1916), which is illustrated by several very detailed maps showing the distribution of towns by symbols to represent populations from one thousand progressively to one million and over.

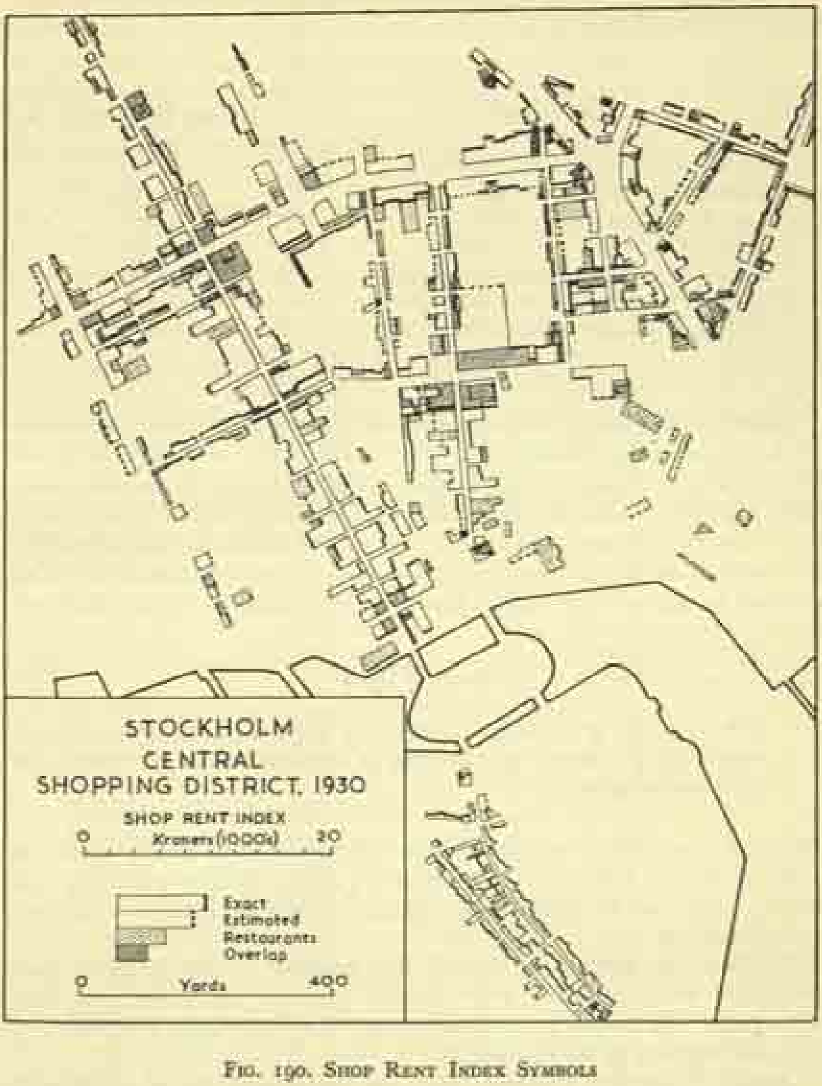


FIG. 190. SHOP RENT INDEX SYMBOLS

Based on W. William-Olsson *et al.*, 'Stockholm', *Geographical Review*, vol. 30, p. 246 (New York, 1940).

Intensity of shopping is proportional to size of symbol. Overlap of symbols has been shaded as a further measure of intensity.

is that by W. Christaller for southern Germany, in which he suggested the following classification:[1]

Settlement	*Average Population*
Small Market Towns (*Marktort*) . . .	1,000
Market Towns (*Amtsort*) . . .	2,000
Local Centres (*Kreisstadt*) . . .	4,000
District Centres (*Bezirkstadt*) . .	10,000
Large District Centres (*Gaustadt*) . .	30,000
Provincial Centres (*Provincestadt*) . .	100,000
Regional Centres (*Landstadt*) . .	500,000

Centrality. The size of its population is, however, only one indication of the regional significance of a town. Some towns with a large population, such as the agricultural villages of parts of the Danubian plain, have relatively under-developed regional functions. Urban geographers have therefore devised many other methods of measuring the centrality of a town, in addition to employing the size of its population. Christaller devised an index of centrality based on telephone services as follows:

$$C = t - \left(\frac{pT}{P}\right)$$

where C = index of centrality, t = number of telephones in a town, p = town's population, T = number of telephones in the whole region, P = population of the whole region.

Hence a town with a telephone density equal to that for the region as a whole would have an index equal to unity. Indices equal to and above unity can be plotted as regional centres by means of proportional symbols.

E. Neef has recently criticized this method on the grounds that telephone ratios indicate only certain regional functions, and that Christaller fails to take into account important geographical differences between regions in his concept.[2]

Nature of Buildings. Irrespective of the nature and size of its population, a town's buildings may afford an indication of its place in the urban hierarchy. The number of banks in a town, for example, is to some extent a measure of its regional importance relative to other

[1] W. Christaller. *Die Zentrale Orte in Süddeutschland* (Jena, 1935).

[2] E. Neef, 'Das Problem der Zentralen Orte', *Petermann's Geographische Mitteilungen*, vol. 94 (Gotha, 1950).

towns. The presence or otherwise of specialized retail stores, of department stores, of a newspaper, of a hospital, or of a university are other features to be taken into consideration. Major cities, for example, according to A. E. Smailes, should contain certain government departments, a stock exchange, and a main branch of the Bank of England; they should have a daily morning newspaper, a university or university college, and a medical school. Main towns should incorporate three or four banks, a grammar school, a cinema, a hospital and a weekly newspaper. Sub-towns lack one or two of these services and urban villages lack two or three.[1]

Functional Classification of Towns. Symbols may be employed to show the distribution of towns according to their major functions (Fig. 191). These may be determined by a number of methods. Analysis of the occupational and industrial structure of urban populations is the method principally adopted to determine functional type. Functional analysis along these lines has already been mentioned in chapter V (pp. 259-61). It should be stressed here that one of the difficulties in analysing occupational structure is the deficiency of population data based on place of work.

England and Wales: Industrial Structure

Industry	*Percentage of Labour Force Employed*
Manufacturing	34·5
Servicing of all types . . .	34·5
Financial Services	2
Transport and Communication .	7
Administration and Defence . .	8
Mining	7
Fishing and Agriculture . . .	7

The chief types of towns comprise manufacturing centres, retail centres, wholesale centres, transport centres, mining centres, health resorts, entertainment and residential centres, educational centres, administrative centres, and large towns with diversified functions. Of course, all towns do perform a diversity of functions in varying proportions. The major function of the town is not necessarily that in which the major part of its population is engaged, but that in which an unusually large proportion of its population is engaged (Fig. 161). In considering the classification of towns along these lines, the general averages for England and Wales given above form a useful working basis.

[1] For details of a comprehensive classification, see A. E. Smailes, 'The Urban Hierarchy of England and Wales', *Geography*, vol. 24 (London, 1944).

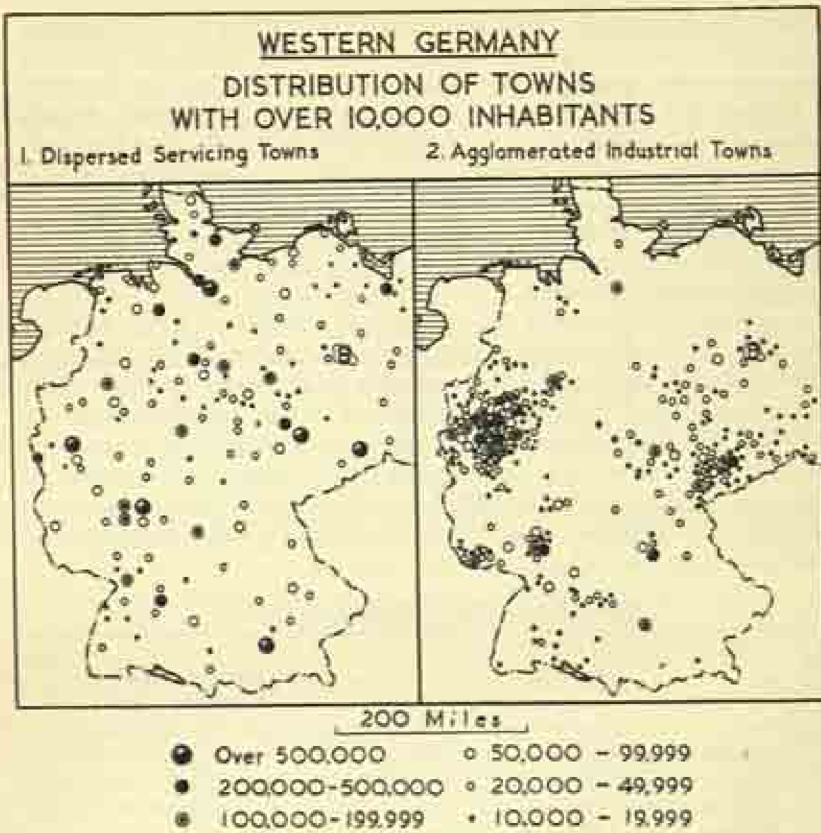


FIG. 191. FUNCTIONAL TOWN SYMBOLS

Based on H. Bobek, 'Uber einige functionelle Stadttypen und ihre Beziehungen zum Lande', *Comptes Rendus du Congrès International de Géographie, Amsterdam, 1938*, vol. 2, section 3a, p. 102 (Leiden, 1938).

Berlin is indicated on each map by the letter **B**. The maps not only bring out the contrast between the disperal of servicing towns and the agglomeration of industrial towns but also indicate that the hierarchy of industrial towns is not so well developed as in the case of the servicing towns. There are, for example, few large industrial towns, i.e. with a population of over half a million.

For fuller details of the classification of towns and cities by function with the aid of occupational data, reference might be made to the work of C. D. Harris.[1]

Variegated symbols may be employed to indicate the different functional types of towns and cities. Because they stand for something rather different from the conventional town symbols, functional symbols might be given a rather different character. For this reason stars and triangles are rather more effective than small dots and squares.

It might be noted that Olssen, in a map depicting the economic structure of Sweden, employed a series of proportional spheres to show the distribution of settlements, coloured variously according to their specific functions. This device enabled the size of settlements to be indicated as well as their functions (see p. 253).

Forms of Settlement. The form of a settlement often, though not always, provides evidence of its origins, together with some indication of the changes which have taken place in its function and character since its foundation. Symbols may be effectively employed to show the forms of settlement when the scale of the map is not sufficient to show the actual street-plan and building patterns. The classification of forms of settlement to be adopted may be based on traditional types such as street-villages, green-villages, *bastides*, 'checker-board' towns and concentric towns. More elaborate classifications may be employed for specific purposes, such as that used by M. R. G. Conzen in his portrayal of the forms of settlement in North-east England.[2]

Site. The mapping of the distribution of different types of settlement sites may be executed most easily and efficiently by symbols. Sites which make use of the defensive possibilities of hill tops, of islands and of meanders, which are at wet or dry points, sites which exploit the commercial possibilities of river crossings or route convergences, are but a few instances of possible types. S. H. Beaver makes use of symbols in maps to show the distribution of hill-top, valley-bottom and spring-line villages in Northamptonshire.[3]

Dates of Foundation. The plotting of the dates of the foundation of towns may afford useful evidence concerning the spread of settlement and of economic organization in frontier lands. A map of this type has been compiled by R. E. Dickinson.[4]

The Sphere of Influence of Towns. Certain aspects of the sphere of

[1] C. D. Harris, 'A Functional Classification of Cities in the United States', *Geographical Review*, vol. 33 (New York, 1943).

[2] M. R. G. Conzen, 'Modern Settlement', *Scientific Survey of North-Eastern England*, British Association for the Advancement of Science (Newcastle, 1949).

[3] S. H. Beaver, *The Land of Britain*, Part 58 (London, 1943).

[4] R. E. Dickinson, 'The Medieval Towns of Eastern German Lands', *Geography*, vol. 27 (London, 1942).

influence of towns may be effectively portrayed by symbols. Variegated symbols, for example, may be employed to show the distribution of the sources of daily labour of neighbouring towns. The affinities of villages to various regional centres, as shown by shopping habits, by newspaper circulation, by the provision of special services such as higher educational institutes and hospitals, can be shown by means of symbols (Fig. 192). The symbolic method has certain advantages over the lineal delimitation of urban fields, because it reflects both the overlap and specialization of services provided by different regional centres.[1]

Place-Name Elements

The plotting of place-name elements by means of symbols is of considerable help in the evolutionary study of settlement. Mention has already been made (see p. 282) of the English Place-Name Society and its series of county volumes, which may be used to plot the distribution of certain early place-name elements.[2] For example, Celtic, Anglo-Saxon and Scandinavian elements have been plotted in Fig. 193. One-inch or 1:25,000 topographical maps must be consulted in order that certain place-names can be located. It should be borne in mind that it is not always necessary to plot every variety of place-name to reconstruct the distribution of early settlement. One or two types are often sufficient to give the broad distribution, and detailed plotting serves only to emphasize this distribution. Interpretation of the patterns of distributions in the light of geographical circumstances can be facilitated by mapping distribution of relief, drift geology, soils and drainage, on a scale similar to that of the distribution map.

Choropleth Maps

Dispersion and Concentration of Settlements

In the study of settlement over wide areas, building traces become cumbersome to use, and it is often impossible to analyse the scatter of settlements by inspection alone. It becomes imperative to devise some means of quantitative analysis of the settlement pattern, and students of settlement have long concerned themselves with the problem of evolving formulae for this purpose. In considering dispersion and concentration of settlements, for example, a number of variables have to be considered. These include (*a*) the number of settlements, (*b*) the number of houses in each settlement; (*c*) the size of the population in each settlement; (*d*) the area of the region served by each

[1] For a good example of the effective use of symbols combined with lineal demarcation, see H. E. Bracey, *op. cit.* From a series of symbolic maps he is able to derive 'median' boundaries between the spheres of influence of neighbouring towns. See also A. E. Smailes, 'The Analysis and Delimitation of Urban Fields', *Geography*, vol. 32 (London, 1947).

[2] See an application in H. C. Darby (ed.), *An Historical Geography of England before 1800*, p. 112 (Cambridge, 1936).

Based on a manuscript map compiled by A. E. Smailes in his capacity as chairman of a standing committee of the Geographical Association on urban spheres of influence. The map gives a measure of the function of various towns in Dorset as shopping centres.

Data for the map were obtained from questionnaires circulated to schools in Dorset. References to towns centres on the map are as follows: **A.** Axminster; **Bl.** Blandford; **Bo.** Bournemouth; **Br.** Bridport; **C.** Crewkerne; **D.** Dorchester; **G.** Gillingham; **R.** Ringwood; **Sa.** Salisbury; **Sha.** Shaftesbury; **She.** Sherborne; **St.** Stalbridge; **Sw.** Swanage; **Wa.** Wareham; **We.** Weymouth; **Y.** Yeovil.

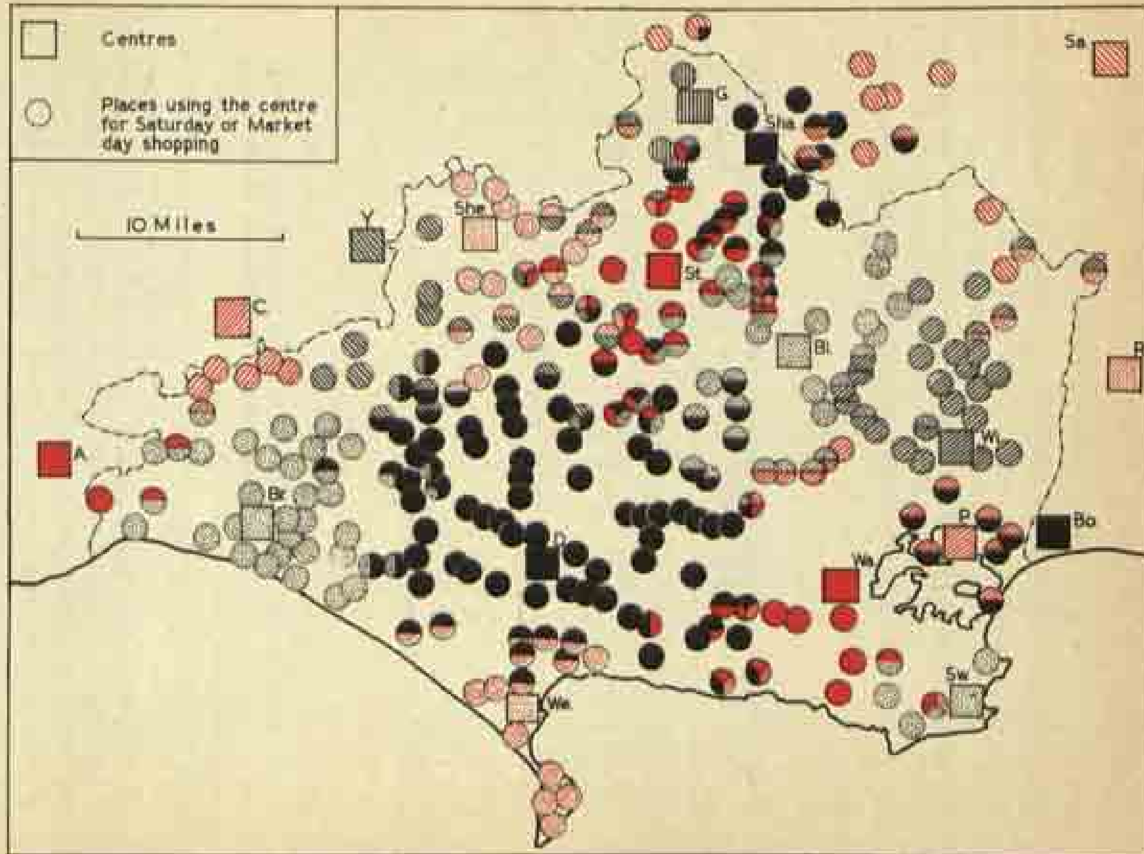


FIG. 192. SHOPPING AFFINITIES BY SYMBOLS

settlement; and (*e*) the distance apart of settlements. No one formula has ever been satisfactorily devised which would take all these variables into consideration, but a number of indices, in which two or three variables are involved, may be used to map certain distributional aspects. A selection of these may be briefly considered.

Demangeon's Coefficient of Dispersion. This is obtained from the formula:

$$C=\frac{E\times N}{T}$$

where E=population of écarts (population of commune minus that of its chief place), N=number of écarts−1, T=total population.

This calculation is only made possible because in French censuses, returns of population for each commune give two totals—one for the chief place in the commune and one for the population of the *écarts* or isolated settlements. This formula has been applied with excellent results, in a map of the dispersion of settlements in France in the French National Atlas (*op. cit.*).

Simple Index of Dispersion. Unfortunately, British census returns do not differentiate between chief places and isolated settlements in any one parish, but some idea of settlement dispersion may be deduced from the formula:

$$I=\frac{S}{H}$$

where I is the Index of dispersion, S the number of settlements in any parish, and H the number of isolated houses.

A house which is situated a quarter of a mile from any other house is conveniently taken to be isolated.

Bernhard's Index of Concentration. Rather more elaborate and not equally applicable to all regions is J. Bernhard's formula, which takes into account the number of houses, the area under consideration and the number of settlements. Bernhard argues that concentration of settlement is a function of the number of houses in each settlement *H/S* and of the number of settlements in a given area *A/S*.[1] Considering both functions, he obtains the formula:

$$C=\left(\frac{H}{S}\right)\left(\frac{A}{S}\right)=\frac{HA}{S^2}$$

[1] Jean Bernhard, 'Une formule pour la cartographie de l'habitat rural avec application au départment de l'Yonne', *Comptes Rendus du Congrès International de Géographie, Paris, 1931*, vol. 3 (Paris, 1934.)

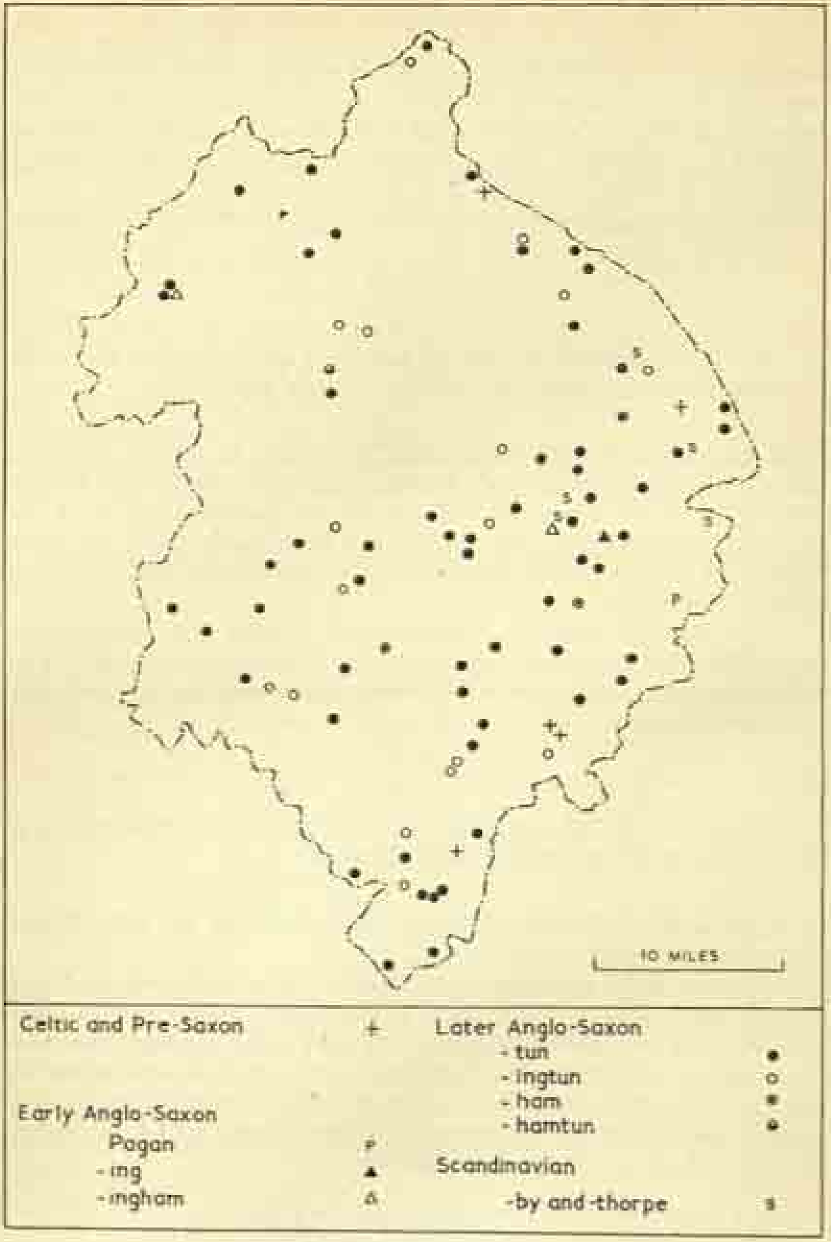


FIG. 193. PLACE-NAME SYMBOLS

Source of data: J. E. B. Gover *et al.*, 'The Place-Names of Warwickshire', *English Place-Name Society*, vol. 13 (Cambridge, 1936).

The map shows the distribution of certain place-names in Warwickshire, with the aim of indicating the pattern of early settlement in the county.

Pawlowski's Indices of Concentration. S. Pawlowski in a study of settlement concentration in Poland[1] used the following formulae derived from settlement traces which had been gridded with a network of 25 kilometre squares:

$$\textit{Mean value of Concentration} = \frac{As}{S} \quad . \quad . \quad . \quad (1)$$

where As=area occupied by the settlements in km.² and S=number of settlements.

This value will vary between 0 and 1.

$$\textit{Coefficient of Concentration} = \frac{A}{A_s} \quad . \quad . \quad . \quad (2)$$

where A=the area of one square (25 km.²) and A_s=area occupied by settlements.

The area occupied by settlements includes the area of gardens, etc., and compares with areas marked red and purple on the British Land Utilisation Survey maps.

Kant's Index of Concentration. A most ingenious formula to show density of rural settlements was devised by E. Kant (*op. cit.*) to illustrate settlement in Esthonia. It was designed to be used to reduce a map showing distribution of habitations by means of non-quantitative dot-symbols to one in which dispersion and concentration of settlement was more precisely reflected in terms of distance between the habitations. The formula is:

$$X = \frac{1}{M}\sqrt{\frac{A}{D}}$$

where X is the relative interval between two settlements, $1/M$ is the scale of the map, A is equal to the area under consideration, and D the density of habitations.

Settlement Groupings

The size of settlements and the grouping of houses in settlements may be indicated by adopting the following coefficient of grouping (C):

$$C = \frac{\textit{Number of Inhabitants in the Parish}}{\textit{The Number of Settlements in the Parish}}$$

Population totals in this case are yielded by census returns, and the number of settlements in a parish have to be counted from contemporary topographical maps. Another possible coefficient (C_1) is as follows:

[1] S. Pawlowski, 'Encore une Méthode de Représentation Cartographique Générale de l'Habitat Rural', *Comptes Rendus du Congrès International de Géographie, Amsterdam, 1938*, vol. 2, section A (Leiden, 1938).

$$C_1 = \frac{\textit{Number of Houses in the Parish}}{\textit{The Number of Settlements in the Parish}}$$

Information about numbers of houses is also yielded by census returns.

Density of Housing

The density of housing in any district is conventionally expressed as the ratio of the number of houses per unit of area (Fig. 194). This

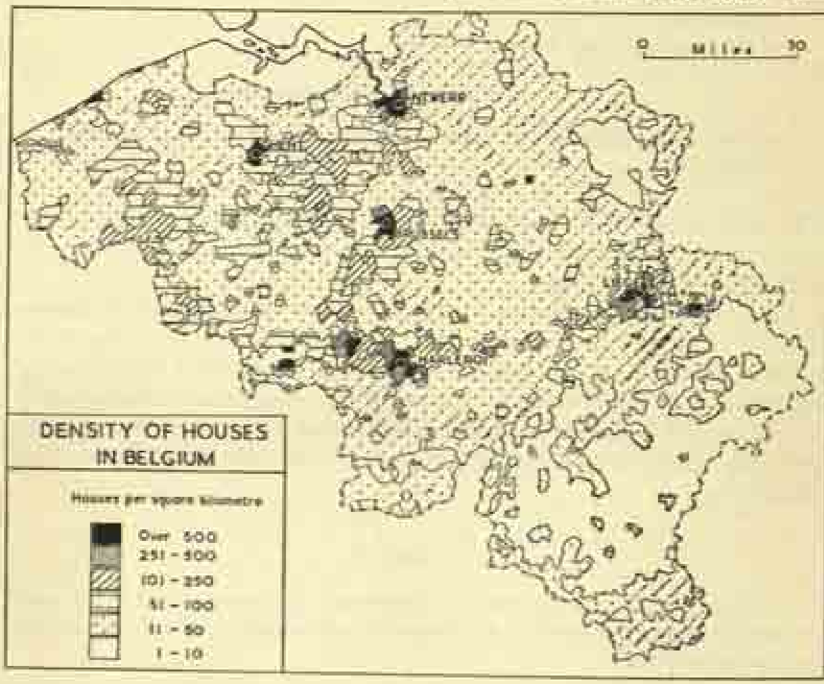


FIG. 194. A CHOROPLETH MAP OF HOUSING DENSITY

Based on M. A. Lefèvre, 'Carte de Densités des Maisons en Belgique', *L'Habitat rural en Belgique* (Liège, 1926).

ratio, however, is not always reliable, because it is very often invalidated by the inclusion of extensive areas of parkland, land taken up by industrial sites, cemeteries and so on. For some purposes a *comparative density of housing* is useful, which is expressed by the ratio of the number of houses per unit of area of land used for residential purposes only.

Residential Structure

The census returns for the wards, blocks of buildings, or 'tracts' of big cities provide data whereby the social and residential structure

of the city may be analysed geographically, largely by means of choropleth maps based on certain indices. J. Moscheles, the Czech geographer, has demonstrated how such analyses may be carried out.[1] Significant indices comprize the percentage of males over 25, to give an immediate indication of the distribution of sex-ratio in the town and the number of domestic servants per 100 houses, to give an indication of grades of residential property. Other indices include the percentage of the residential population gainfully employed, the number of families per house, and so on.

Isopleth Maps

Isopleths do not have a very wide application in the cartographical study of settlements. They are used largely as a means of simplifying distributional aspects of settlements where generalization is required.[2] Thus J. A. Barnes and A. H. Robinson devised a special formula to obtain an index of dispersion of rural settlement which could be used as a point-value for the interpolation of isopleths.[3] The best measure of dispersion between farm houses, or for that matter between settlements, is their distance apart, but to measure such distances involves great labour. Barnes and Robinson demonstrated that the average distance (D) between farms in any administrative unit closely approximates to:

$$1{\cdot}11\sqrt{\frac{A}{n}}$$

where A is the area of the unit and n the number of farms.

Values of D are plotted in the centre of the unit and isopleths are interpolated in tenths of a mile, or at any distance suitable to the scale of the map (cf. Kant's formula, p. 311).

Polish geographers, who have tended rather to specialize in problems of rural settlements, often combine isopleths with choropleths to show the distribution of rural habitations.[4]

[1] J. Moscheles, 'Prague', *Geographical Review*, vol. 27 (New York, 1937).

[2] See the maps of the distribution of hamlets in U.S.A. by G. T. Trewartha (*op. cit.*). M. Jeśman used isopleths (interpolated from points fixed in each commune according to the mostly densely settled part) to show the general distribution of habitations in Valkynia in 'Gęstość Zabudowania Województwa Wotynskiego' (Density of Buildings in Valkynia), *Prace Wykonane w Zakładzie Geograficznym Uniwersytetu Wileńskiego*, no. 1 (Vilno, 1936).

[3] J. A. Barnes and A. H. Robinson, 'A New Method for the Representation of Dispersed Rural Settlement', *Geographical Review*, vol. 30 (New York, 1940).

[4] M. Zdobnicka, 'Metoda izarytmiczna w grafice statystycznej', *Polski Przegląd Geograficzny* (Warsaw, 1925).

Isochrones

In the delimitation of the sphere of influence of cities, it is desirable to know the time taken in travelling between the city and the countryside. Times can be ascertained for a number of points and isopleths then interpolated for intervals of an hour or so. Isopleths which join places having the same travelling time to the centre of the city are sometimes called *Isochrones* (see also p. 188).[1]

Isostades

The isopleth method may also be used to show spread of organized settlement in frontier districts. Dates of foundation of particular towns are plotted and isopleths interpolated for significant dates. These have been called *isostades*.[2]

Columnar Diagrams and Divided Rectangles

Starting from the axiom that "a qualitative analysis of rural settlement has scientific value only if supported by a quantitative statistical foundation",[3] Miss B. M. Swainson analysed the dispersion and agglomeration of rural settlement in Somerset by means of columnar diagrams, and it is principally in connection with such analyses that these diagrams have so far been employed. But they are also of use in the comparative study of the population structure of different settlements and in the study of differential growth of urban and rural population.

Population and House-Groupings

Miss Swainson devised a system of eight columns to represent a series of house-groupings for contrasting blocks of rural parishes in different parts of Somerset. The heights of the columns were made proportional to the percentage of the total population in each block of parishes. The method is demonstrated in Fig. 195, which has been constructed to show features of the settlement-groupings in Kent.

The data about population and the number of dwellings in a parish may be obtained from census returns, but the house-groupings have to be ascertained by counting the number of houses in each settlement from large-scale maps. There is often difficulty in doing this because individual dwellings are not always distinguished separately on maps, and it frequently happens that anomalies occur between the number

[1] For an example, see E. Kant, a map entitled 'Urban Hinterlands in Estonia with Policentric Isochrones', in *Environment and Population Problems in Estonia* (Tartu, 1934).

[2] G. Cornen, 'East Prussia', *Geography*, vol. 30 (London, 1945).

[3] B. M. Swainson, 'Dispersion and Agglomeration of Rural Settlement in Somerset', *Geography*, vol. 29 (London, 1944).

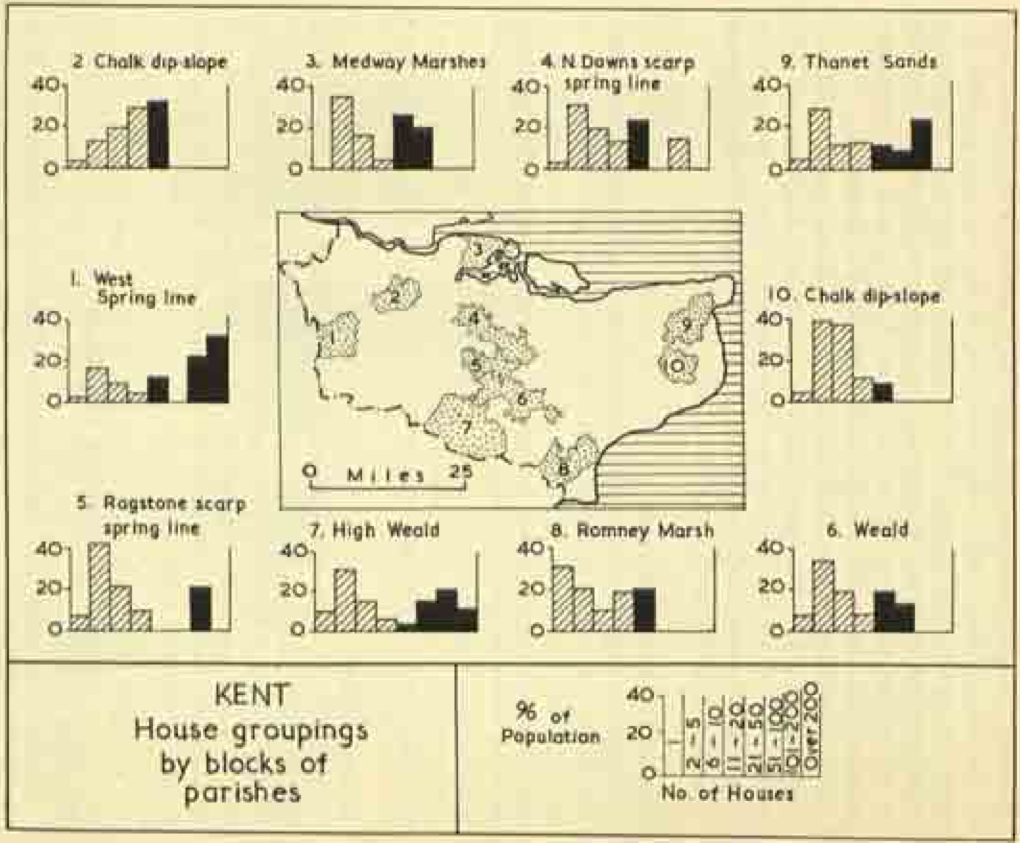


FIG. 195. COLUMNAR DIAGRAMS OF HOUSE-GROUPINGS

Source of data: (1) *Census of England and Wales, 1841*, Enumeration Abstract (London, 1843); (2) The relevant sheets of the One-inch series, Ordnance Survey, first edition.

Columns have been shaded to facilitate comparison: groupings below 21 houses are shown by diagonal shading, and above that figure in black.

of houses counted from the map and the number of houses returned on the census. Some field-work, therefore, is necessary to smooth out these anomalies. The census of 1951 should provide data which will make possible analyses of house-groupings in rural areas which will be of interest not only in the study of the evolution of settlement patterns, but also in the classification of modern settlements.

House-Groupings. Where it is not possible to obtain maps which are contemporaneous with census returns, columnar diagrams may be constructed along similar lines to those outlined above, but with the height of columns made proportional to the number of occasions on which a particular grouping occurs (Fig. 184).

Compound Columnar Diagrams

Diagrams may be constructed proportional in height to the total population of units of area at different periods, and subdivided to show proportions of the population living in large towns, small towns and villages. Some census returns lend themselves readily to such analyses because they contain tables showing totals of enumerated population living in communities of specific sizes, i.e. less than 2,500, 2,500–10,000, and so on.[1] Alternatively, columns may be constructed to show numbers of houses, and divided to distinguish types of houses.[2]

Divided Rectangles

Divided rectangles may be employed in much the same way as compound columnar diagrams to indicate changes in settlement structure as reflected in the urban and rural status of the population. In Fig. 196, for example, comparable rectangles have been constructed to show the state and progress of urbanization in selected European countries between 1870 and 1930.

Special Diagrams

Flow-Line Maps

Traffic-flow maps and the principles of their construction are fully dealt with elsewhere (see p. 213). They deserve a separate mention here, however, because of their use in the delimitation of town and country by means of motor-bus services.[3] The delimitation has a

[1] See an application in Admiralty Geographical Handbook, *Germany*, vol. 3, p. 80 (London, 1944).

[2] See a series of such diagrams arranged in the form of a profile in R. Finley and E. M. Scott, 'A Great Lakes-to-Gulf Profile of Dispersed Dwelling Types', *Geographical Review*, vol. 30 (New York, 1940).

[3] F. H. W. Green, 'Town and Country in Northern Ireland', *Geography*, vol. 34 (London, 1949); and 'Motor-bus Centres in South-west England considered in relation to Population and Shopping Facilities', *Institute of British Geographers, Transactions and Papers*, Publication no. 14 (London, 1949).

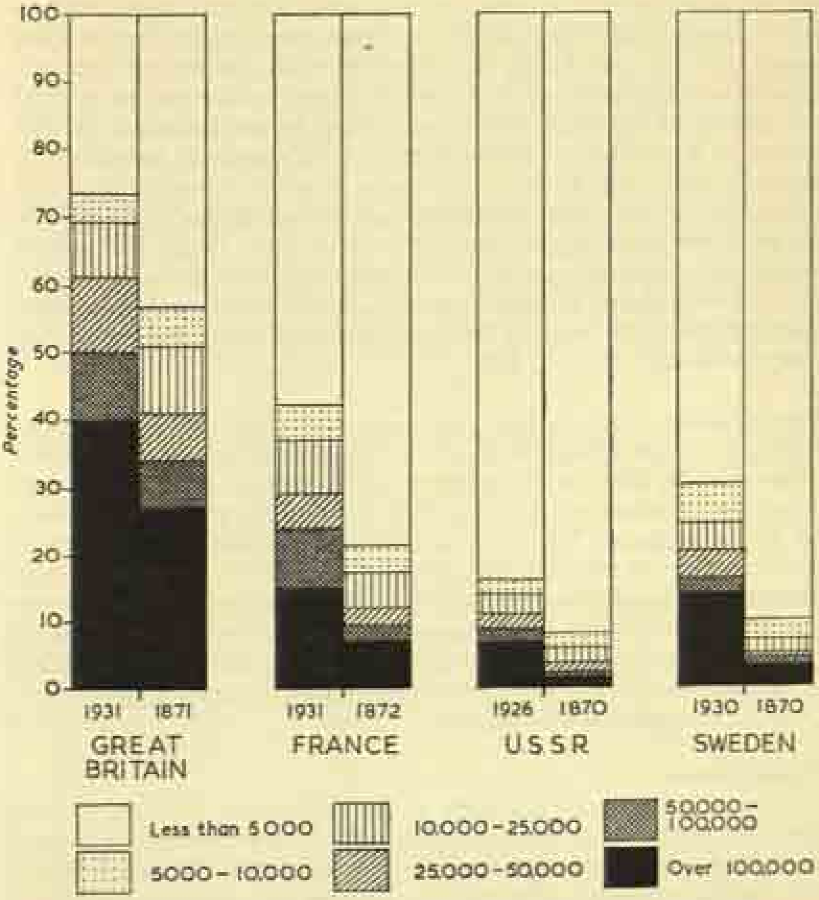


FIG. 196. DIVIDED RECTANGLES OF RURAL AND URBAN POPULATION

Source of data: J. Haliczer, 'Agglomeration und Verteilung der Bevölkerung in Europa auf Grund einer neuen Karte in Masse 1:4,000,000', *Comptes Rendus du Congrès International de Géographie, Amsterdam, 1938*, vol. 2, section 3a (Leiden, 1938).

The diagrams show the relative proportions of the population of various European countries living in places of less than 5,000 inhabitants or in larger places, as the case might be. Changes occurring within the space of about sixty years are also shown, to enable the progress of urbanization to be visually assessed.

reconnaissance value in the determination of the average hinterlands of towns, and in the evaluation of shopping facilities of urban centres. All local services must be taken into consideration. First of all, 'motor-bus centres', from which radiate at least some regular bus services which serve no town larger than themselves, are ascertained from the time-tables. The frequencies of buses employed on the various services are plotted in the form of flow-lines. After an inspection of the diagrams, it is possible to decide where boundaries may be drawn to separate areas within which one centre is more accessible than any other. Certain difficulties arise in the execution of the method. Double-decker buses, for example, may be used on some routes and not on others, and duplicate services are not shown on time-tables. Nevertheless, the compilation of these diagrams constitutes a constructive exercise and paves the way for further analyses of urban hinterlands by other methods.

Ray-Diagrams

Ray-diagrams are used to illustrate aspects of the sphere of influence of towns. The affinities between town centres and villages in the surrounding countryside may be indicated by a line joining the village to the town centre. Thus if a town functions as the shopping centre for a number of neighbouring villages, its function is reflected by a number of rays radiating from the town to the villages. It is an advantage of this method in the delimitation of urban fields that it allows overlap to be shown. It can also be adapted to show a great variety of affinities in a simple but effective manner, for example, the circulation of newspapers (Fig. 197).

Urban Profiles

As a contribution to the study of the morphology of cities, E. van Cleef has made use of 'urban profiles'.[1] They take the form of slightly exaggerated silhouettes of the profiles of cities, with the object of depicting variations in their geographical character in a pictorial manner.

Sketch-Maps

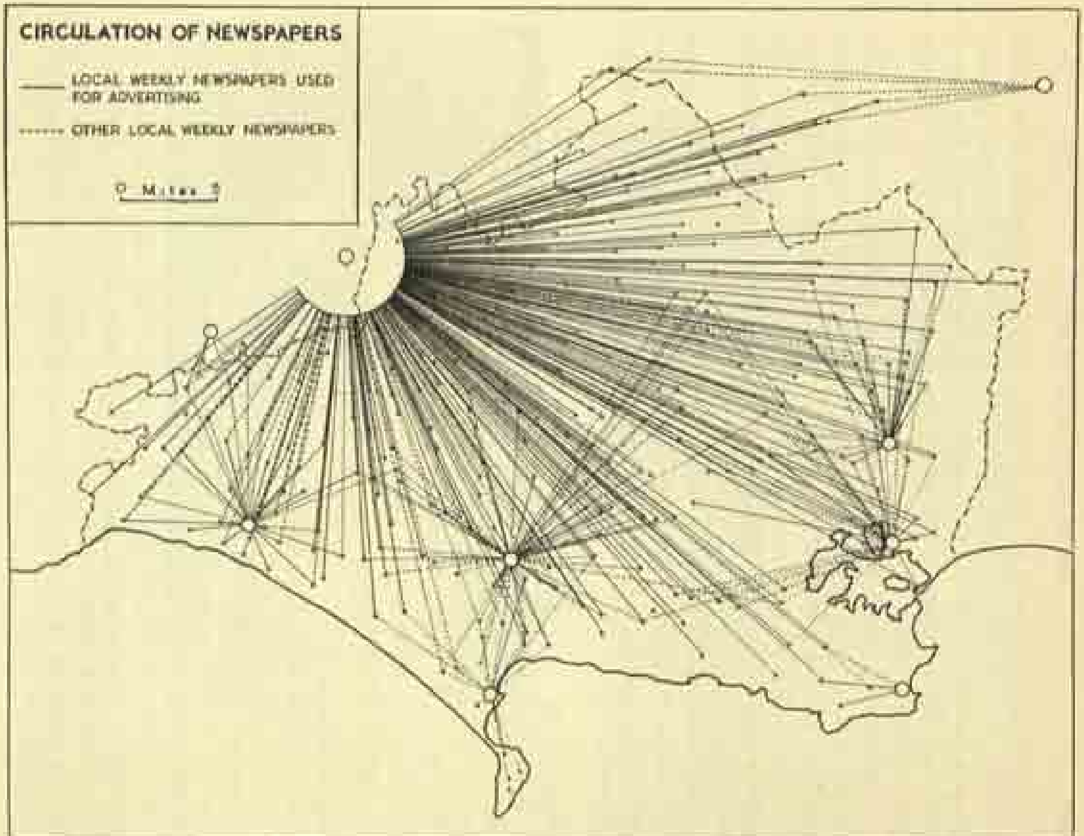
The sketch-map has long been an indispensable tool of the geographer in his illustration of the position and siting of settlements. It also serves to clarify analysis of the form and functions of settlements.[2] Basic data for sketch-maps may be derived in the first instance from topographical maps, for example, key contours, limits of built-up areas, main lines

[1] E. van Cleef, 'The Urban Profile', *Annals of the Association of American Geographers*, vol. 22 (Lancaster, Pa., 1932).

[2] There are some excellent examples in O. H. K. Spate and E. Ahmad, 'Five Cities of the Gangetic Plain', *Geographical Review*, vol. 40 (New York, 1950); and R. E. Dickinson, 'Morphology of Medieval German Towns', *ibid.*, vol. 35 (1945).

FIG. 197. A RAY-DIAGRAM OF NEWSPAPER CIRCULATION

Based on a manuscript map compiled by A. E. Smailes. The map refers to Dorset, and a key to centres is provided in Fig. 192.



of communication and so on. Further details are added from other sources, such as historical and geological maps, to illustrate specific points. Griffith Taylor makes great use of the sketch-map. His use of hachures, his selection of key phenomena, and his method of annotation might be noted.[1]

Diagrammatic Sketch-Maps. Sketch-maps in which the scale is distorted in order to demonstrate relationships between siting and surface features, and in which at the same time space is conserved and an orderly classification effected, have been termed diagrammatic. The word *cartogram* is sometimes though not exclusively used to describe such illustrations.[2]

Generalized Sketch-Maps. A useful exercise in the analysis of the forms of towns entails the construction of generalized diagrams, which incorporate distinctive features of the plan and structure of regional types of towns.[3]

Sketch-Blocks

Block-diagrams (see p. 97) can be very effectively employed in the portrayal of the siting of settlements, and in the analysis of geographical factors influencing their growth and structure.[4] The introduction of the third dimensional aspect often throws light on the operation of geographical factors which two-dimensional plans tend to conceal altogether.

Stage-Diagrams

Sketch-blocks and sketch-maps may be arranged in tiers to demonstrate the evolution of a settlement at different stages during its period of growth (Fig. 198). These have been called *stage-diagrams* by Griffith Taylor. In the construction of such diagrams it is of great help to obtain as many historical maps of the settlement as possible and to reduce these photostatically to the same scale in order to facilitate the process of chronological analysis. The mere mechanical process of reduction and arrangement reveals the operation of geographical factors affecting the growth of settlement which are otherwise easily overlooked.

LINE-GRAPHS

Many problems concerned with the location, size, structure and function of settlements can well be illuminated by graphical illustration, but there are in fact singularly few examples of the application

[1] G. Taylor, *Urban Geography* (London, 1949).

[2] A good example of its application to a classification of settlements in Sussex is to be found in *The Land of Britain*, Parts 83–4, *Sussex* (*East and West*) (London, 1942).

[3] H. J. Fleure makes a reference to the use of these sketch-maps in 'A Generalized Diagram of a City in the Paris Basin', *Geography*, vol. 25 (London, 1940).

[4] For numerous instances of their application, see G. Taylor (*op. cit.*).

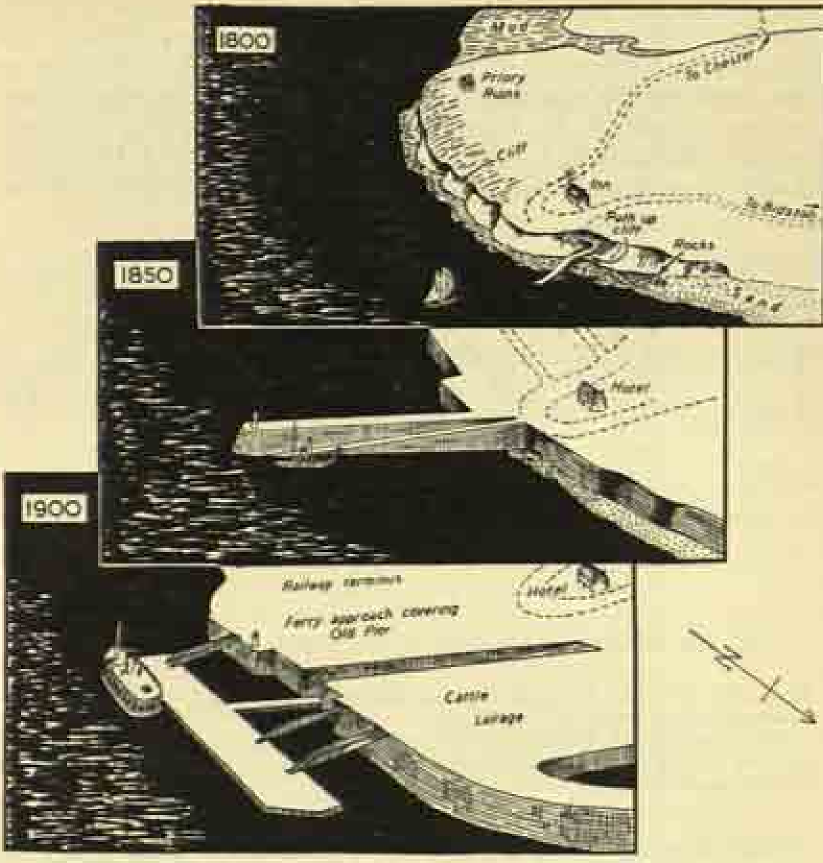


FIG. 198. A STAGE DIAGRAM OF WOODSIDE, BIRKENHEAD

Based on J. E. Allison, *The Mersey Estuary*, p. 19 (Liverpool, 1948).
The diagram sums up changes which have taken place in the landscape of this part of Birkenhead during the course of the nineteenth century.

of graphical methods to settlement problems. Failure to apply graphical methods is due in part to the generally unsuitable form in which raw data about settlements are found. Reference might be made here to the possibility, for example, of plotting the distribution of settlement against altitude. H. W. Ahlmann has an interesting polygraph which relates settlement and altitude in south-eastern Sicily.[1] He plotted height in metres as ordinates, and area, number of inhabitants and

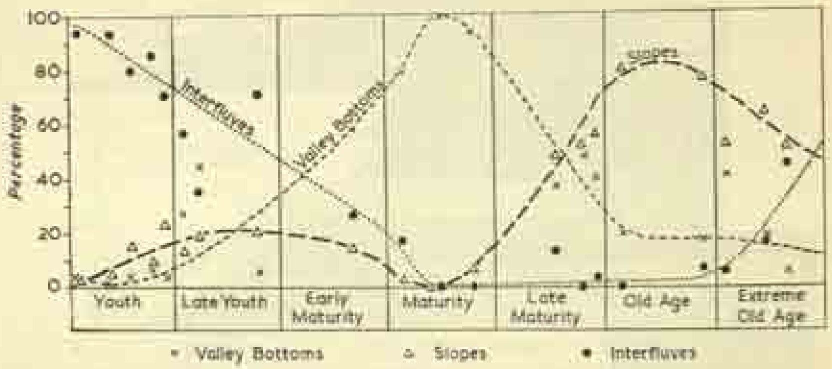


FIG. 199. CURVES OF SETTLEMENT LOCATION IN RELATION TO LAND-FORMS

Based on J. L. Rich, 'Cultural Features and the Physiographic Cycle', *Geographical Review*, vol. 4, p. 300 (New York, 1917).

The frequency with which houses are sited on valley bottoms, slopes and interfluves has been plotted on a percentage basis, and theoretical curves have been drawn to indicate the relationships which emerge.

density of population as abscissae. He thus produced three graphs on the same chart to portray the concentrations of settlement at certain altitudes. The method may have fruitful results in the analysis of settlements in relation to plains of erosion, terraces, northward and southward facing slopes, and so on.

Polygraphs

The relation between land-forms and siting of settlements was the subject of a paper by J. L. Rich, in which he used graphical methods to demonstrate his ideas.[2] He considered the percentage of sites of settlements to be found on the valley bottoms, the slopes and the interfluves respectively of rivers in the period of their youth, their

[1] H. W. Ahlmann, 'The Geographical Study of Settlement', *Geographical Review*, vol. 18 (New York, 1928).

[2] J. L. Rich, 'Cultural Features and the Physiographical Cycle', *Geographical Review*, vol. 4 (New York, 1917).

maturity and their old age, and plotted the results graphically (Fig. 199).

Analysis of the Settlement Net. Another experiment with frequency graphs is worth mentioning as a pointer to their further possibilities.[1] To demonstrate variations in the size and character of settlements in distinctive regions of New South Wales, J. Andrews plotted for each region (*a*) the percentage of the total number of agglomerations as ordinates against the population of each agglomeration as abscissae; and (*b*) the percentage of total population as ordinates against the population of each agglomeration as abscissae. He thus obtained two supplementary sets of polygraphs, which revealed distinctive regional variations in the characteristics of the settlements analysed.

[1] J. Andrews, 'The Settlement Net and the Regional Factor', *Australian Geographer*, vol. 3 (Sydney, 1934).

INDEX

Printed in Great Britain by
The Camelot Press Ltd., London and Southampton