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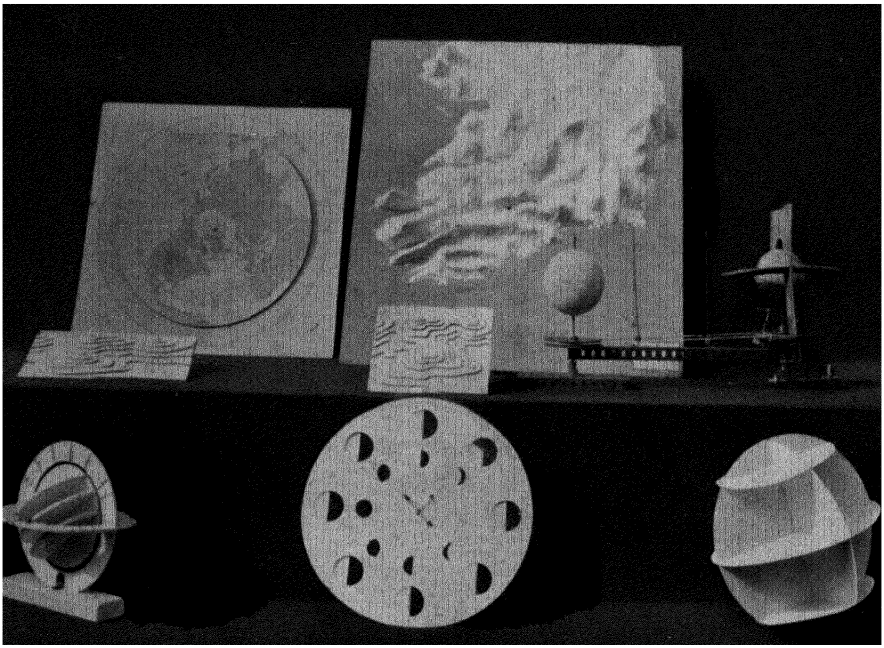

A selection of some of the models described in the text

Longitude-time wheel; Relief model of S. Ireland; Layer relief models (uncovered); Meccano tellurion; The sun-path instrument, phases of the moon model, and the cardboard ball

PRACTICAL AND EXPERIMENTAL GEOGRAPHY

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PREFACE

AN experimental and practical approach in teaching certain subjects is often of great assistance in stimulating interest, facilitating understanding, and fixing the essential facts in the minds of the pupils and students. Certain aspects of geography are particularly well suited to this type of treatment, and doubtless many teachers in schools, training colleges, and university departments will have already introduced this type of work into their syllabuses.

This book is a first attempt to gather together many of these exercises: some suggestions have already appeared in print and are duly acknowledged, others are in circulation although apparently not recorded, whilst some methods described have been evolved by the authors themselves. It is hoped that the compilation will be found acceptable to a wide audience, not in any way as a course book—a knowledge on the part of the reader of the relevant parts of the subject being naturally presumed—but rather as a selection of stimulating ideas. Doubtless few will feel the need to attempt all the models and practical suggestions outlined, but it is hoped that most readers will find many ideas of assistance to them in their work. No attempt has been made to grade the suggestions, which have been arranged in relevant groups, since the interested reader will in any case be making his own selection.

It is often maintained that time for practical work by pupils is more readily available in secondary modern schools than in secondary grammar schools: the grammar school is perhaps more tied to a timetable, but there is often much free time available after public examinations. Training colleges will, it is hoped, find the compilation of much assistance: at this level the practically minded student should be capable of undertaking the more advanced suggestions and may well improve upon many of the ideas. The authors would be glad to include, with due acknowledgement, in possible future editions of this book, any such improvements or suitable additional ideas not at present covered.

Many thanks are due to Professor F. Debenham, Mr. Norman Pye and Miss Alice Coleman, for assistance in the compilation of the book, and also to Mr. T. L. Garfield Pascoe for the frontispiece photograph.

W. G. V. B.
A. W. R.

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SECTION A

THE EARTH'S MOVEMENTS AND SOME EFFECTS

THE rotation of the earth, its movements, the creation of night and day and the seasons form a background on which the geography teacher will be filling in later on the details of human activities in selected areas. It is therefore important that young pupils should grasp the fundamental facts of the earth's movements and retain them from the beginning free from confusion: in this work the model becomes of great value, especially as the subject-matter is necessarily usually introduced at a fairly early stage in the syllabus.

Though the blackboard will always provide the geographer's principal means of expression, many pupils find it difficult to visualize a problem in three directions when drawn as a plane diagram. In such cases the use of a three-dimensional model is an invaluable aid and will lead on naturally to an understanding of flat models, where the earth may be represented by a flat disk. These, in their turn, will facilitate an appreciation by the slower pupil of the two-dimensional sketch diagram.

1 Latitude and Longitude—The Cardboard Ball

An early problem is a satisfactory explanation of the use of latitude and longitude to define positions on the earth's surface. These units are related to the earth's rotation, for both the poles and the equator are defined by the rotation. Blackboard diagrams may not be followed easily unless preceded by or accompanied with models. Various methods will probably suggest themselves to the interested teacher—e.g. the use of a wooden sphere with sections cut away down to the centre to show the angle of latitude and longitude for some particular place; alternatively wire constructions may be attempted, although these may not be so effective as the cut-away wooden sphere.

If time permits, a more effective method, which is calculated to leave perhaps a more lasting impression, would be to arrange for the pupils themselves to construct a model, and for this the 'cardboard ball' may be recommended. This is made as follows: three equal circles are cut from suitable cardboard. Bristol board or strong postcards are recommended for this, and all models where folding is necessary, as thicker cardboard is liable to crack.

In the circles slits sufficiently wide to take the thickness of the cardboard are cut, as shown in fig. 1 (*a*). A fourth, smaller circle (*f*) is cut to represent a parallel of latitude: in this case New York has been shown. On this circle similar slits as shown are cut.

The two meridians are first interlocked. This is accomplished by folding the Greenwich meridian card (*b*) along the lines marked *X–X*. This card can then be inserted through the central slit of the other meridian card (*a*). Both meridian cards are then passed through the cross cut in the equatorial card (*d*) by folding them back along the lines marked *Y–Y*. Finally the parallel of New York (*f*) is slipped into position by folding the meridian cards along the lines *W–W*. The result is shown in (*e*).

If desired, a number of parallels may be securely fixed in this model, but it is not possible to interlock more than two meridians. Others, however, may be cut in the form shown (*c*) and secured by transparent adhesive tape.

Each pupil in a class should make his own individual model, following the teacher step by step in the construction of a larger demonstration model. The latter can be used for general instruction in latitude and longitude, and also for clarifying ideas on great and small circles. All the pupils should write clearly on their models the captions as shown in the accompanying diagrams.

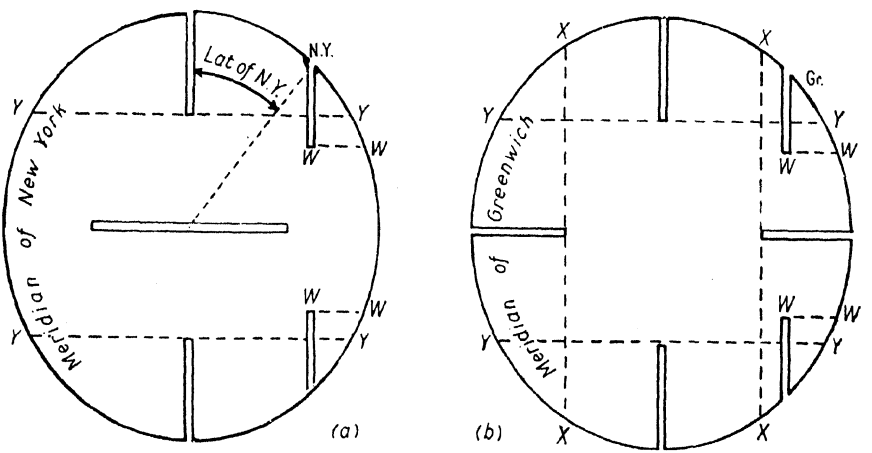


Fig. 1 (*a*), (*b*).—The cardboard ball.

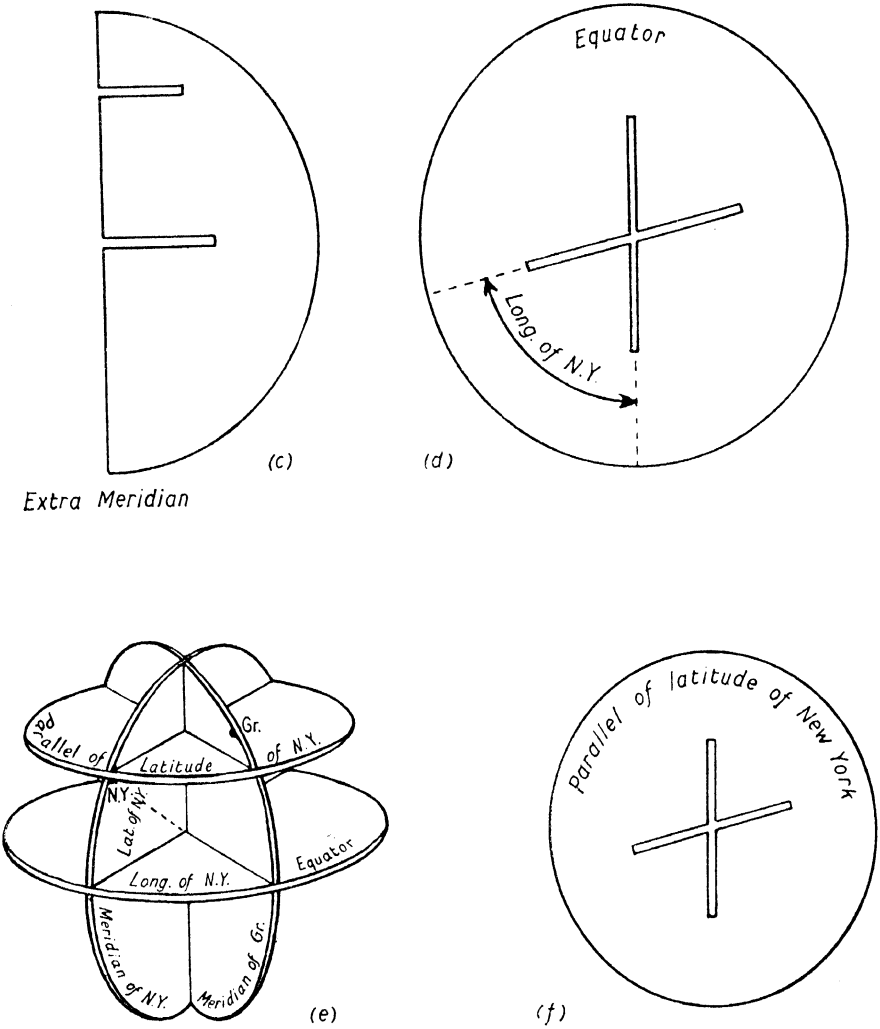


Fig. 1 (*c*), (*d*), (*e*), (*f*).—The cardboard ball.

2 Experiments to demonstrate the effect of

(a) The Elevation of the Sun and

(b) The Duration of Daylight

In teaching younger pupils it may be advisable to begin with investigations of the apparent behaviour of the sun in the heavens before the actual details of the seasons are attempted. The path of the sun across the sky can be plotted at various times of the year by a number of methods, some of which are described in the following pages. Once it is realized that the sun rises higher in the sky and shines for a longer period in summer than in winter, it is a simple matter to connect these facts with the difference in temperature between the seasons.

A laboratory experiment may, however, be undertaken which will further facilitate a rapid appreciation of the essential facts. A large sheet of cardboard painted with Bulin black should be placed upon a table. A little to one side is fixed an electric bowl fire which can be turned in a vertical plane about a horizontal axis. In front of the guard a sheet of asbestos is fixed at right angles to the rays of the fire; in the centre of the sheet a circular hole is cut.

The rays of the fire may be directed on to the blackened surface at any desired angle, either by turning the bowl of the fire or, preferably, by lifting it higher, whilst keeping it at the *same distance* from the part of the board to which the rays are directed in either case. By touch alone the pupils can detect the difference in temperature of the horizontal surface produced as a result of (*a*) differences in the angle of incidence and (*b*) differences in the duration of exposure.

If two fires are available both hands can be used for detection of temperature differences produced through varying angles of incidence and differing periods of duration of the rays. From these simple experiments the teacher may lead on to a description of the way in which the varying elevation of the sun and differences in the duration of the daylight underlie the temperature differences associated with the seasons.

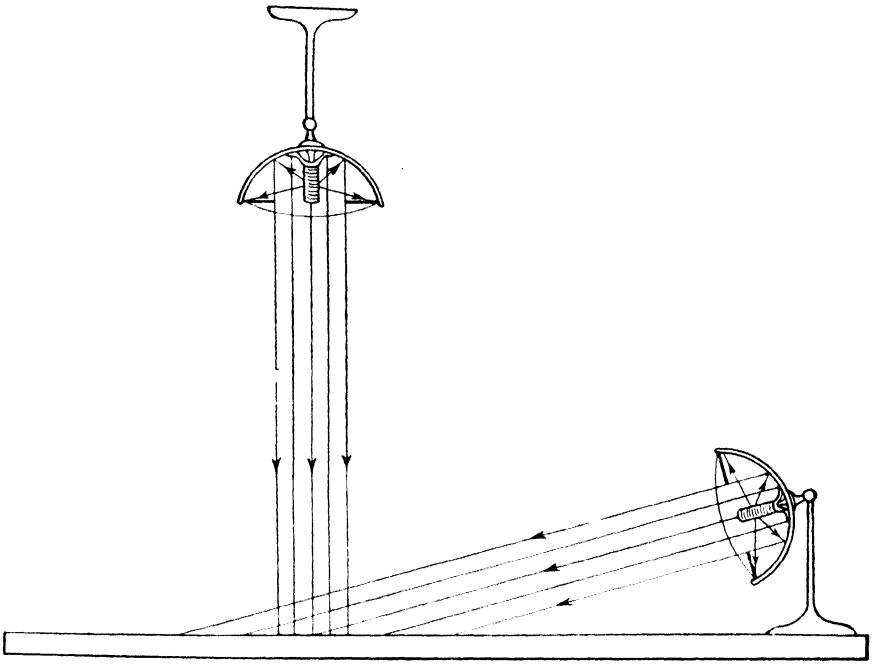


Fig. 2.—Apparatus to demonstrate the effect of the elevation of the sun and the duration of daylight.

Note. This experiment can be further extended to demonstrate the way in which different surfaces (e.g. soils and vegetation) will give slightly different temperatures when exposed under the same conditions. This is explained by the different heat capacities and conductivities of the media. In the laboratory clays, sands, loams and wood might be compared, actual temperatures being measured by means of thermometers protected from the direct rays emanating from the heat source.

3 Model Tellurions

(a) A Static Model to Show the Seasons

The simple model shown in fig. 3 should prove of value when used either independently or in conjunction with the usual blackboard representations. The plane of the ecliptic is a square of three-ply wood or other suitable material in which circular holes are bored to contain balls which represent the sun and the earth. The dimensions of the apparatus will depend upon the type of spheres available. Old tennis balls are well suited to represent the earth, and on these the equator, tropics, and polar circles should be carefully drawn. A long needle passed through each ball serves for the axis and indicates the position of the poles.

A movable cardboard frame (*a*, *b*, *c*) is made to fit as closely as possible over the balls. The upright plane of the frame serves to divide the dark and sunlit portions of the earth. A wooden base similar to that illustrated in the elevation is required to support the plane of the ecliptic. The depth of the base could be arranged so that the balls rest upon it, but in that case the sun might have to be represented by a sphere equal in size to the others. Alternatively, the balls could rest on wooden blocks fixed to the base and of suitable height.

The model may be used to demonstrate the varying lengths of day and night in different latitudes, the latitude of the overhead sun at different seasons and the changing elevation of the sun at noon. The construction is capable of further development at the teacher's discretion, e.g. the needles may be made long enough to rest on the base, thus enabling the earth to be rotated by hand, provided the circular holes are large enough. A more elaborate model could also be attempted in which, say, eight positions are shown and the earth's orbit made elliptical.

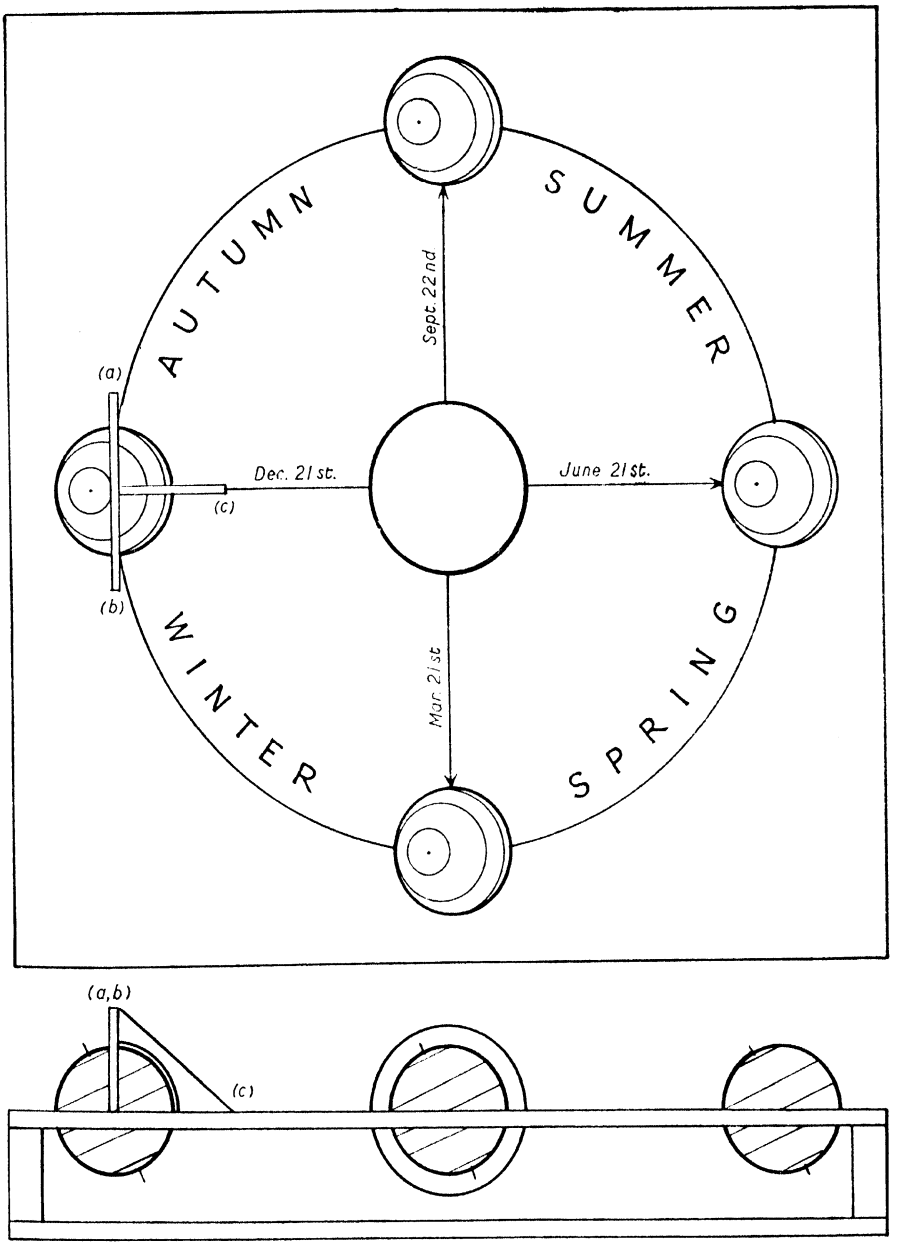


Fig. 3.—A static model tellurion.

(b) A Meccano Tellurion

When pupils have assimilated the connexion between the varying elevation of the sun, the duration of sunlight, and the changes of temperature during the year, an attempt may be made to explain the revolution of the earth which is fundamentally the cause of the facts. The controversies which waged round early efforts to describe the phenomena involved are themselves evidence of the difficulties encountered by students. A good tellurion or orrery will be found to facilitate an understanding of the principles, and a serviceable model is not difficult to make.

The tellurion illustrated in fig. 4, and shown in end elevation in fig. 5, is mainly constructed from Meccano parts and two india-rubber balls. The latter are used to represent the sun and earth. The parallels and meridians on the ball representing the earth are easily drawn, either by making a small turntable of Meccano parts for the ball, or by cutting a series of holes, the appropriate sizes, in pieces of card which can fit over the ball to act as guide-lines.

The essentials of a good model are that the earth shall rotate both quickly, and in the same direction, as it is made to revolve round the sun whilst its axis must preserve a constant direction in space. In the model illustrated the earth was found to rotate nearly fifty times during each revolution. This is much better than some elaborate models which can be purchased, but still falls far short of the three hundred and sixty-five rotations needed for a scale model.

The seasonal variation of the angle of the sun's rays in different latitudes and at different times of the year are clearly shown by the knitting needles, whilst pins can be inserted to indicate the zenith. The division of the solar day between daylight and darkness is also clarified by the use of a cardboard screen, one side of which is painted white and the other black.

DETAILS OF CONSTRUCTION. Meccano enthusiasts should find the diagrams on pages 10 and 11 sufficiently clear to assemble a working model therefrom without further detailed instructions. For convenience, a list of the required parts is given below. Model engineering constructors, of which every class has its quota, may be able to improve on the apparatus illustrated which was devised and constructed, under supervision, by a boy of thirteen.

Meccano parts required:

Number	Quantity	Number	Quantity
2	1	25	2
5	3	27*a*	1
8	2	29	1
11	1	35	1
14	1	37	16
15*a*	1	44	1
16*a*	1	52	1
17	1	59	5
19*b*	2	125	1
22	1	126	4
24	1	142*c*	1

Additional requirements:

Four screws, five steel knitting needles
Cord for pulleys, two balls for the earth and sun
Small piece of wood to hold knitting needles
Suitable cardboard for the equatorial plane and night/day screen.

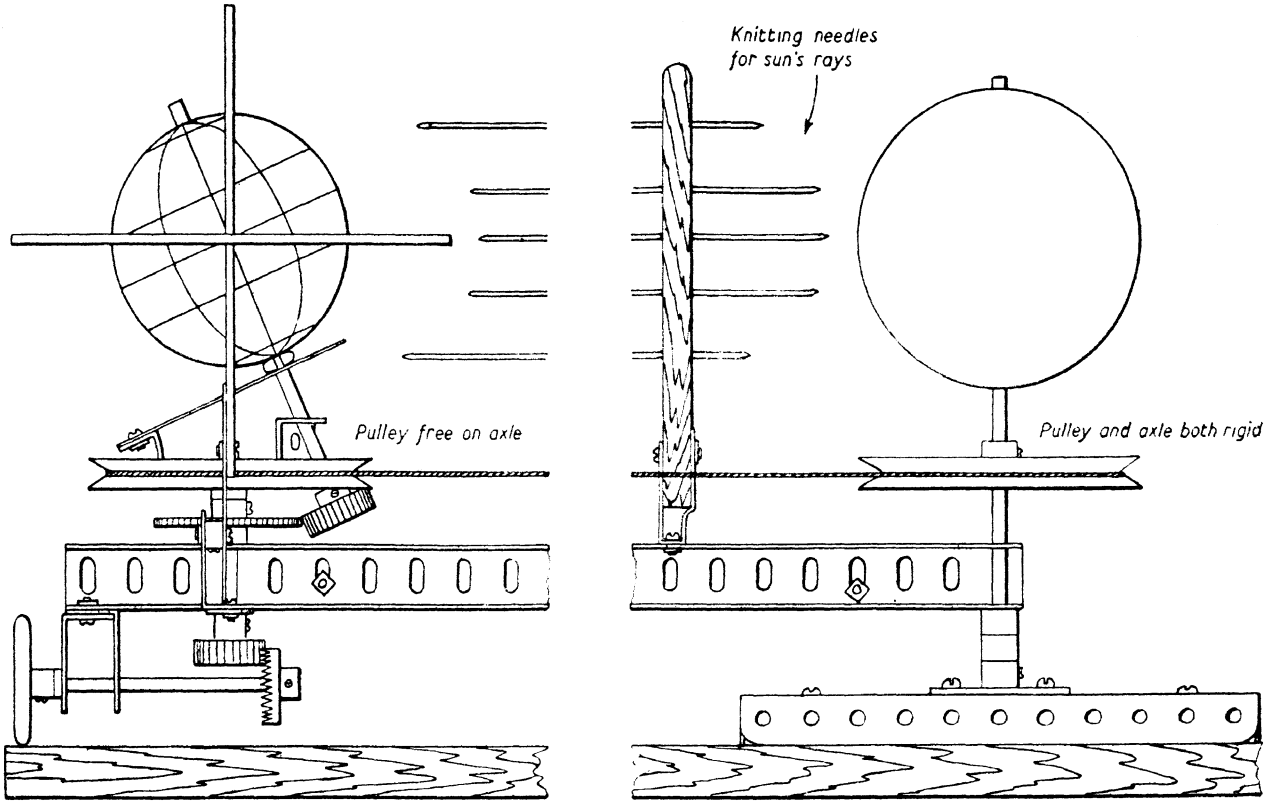


Fig. 4.—A Meccano tellurion.

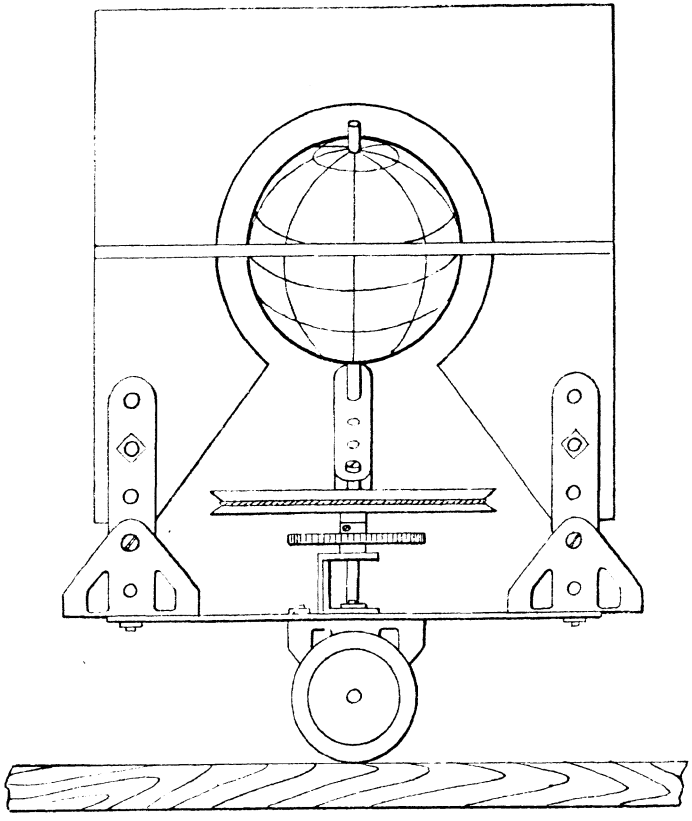


Fig. 5.—End elevation of the Meccano tellurion.

(c) The Dissanaike Tellurion

The model shown in fig. 6 was originally proposed by A. W. Dissanaike, and is described in *The Geographical Teacher* (now *Geography*), Vol. XII, Part 6. It consists of a stand with a circular top (*a*, *b*, *c*) made of wood or other material $\frac{1}{8}$ in. to $\frac{1}{4}$ in. thick (the thinner the better); this is divided into twelve parts, one division for each month of the year. A revolving arm (*d*, *e*) is fixed below this, at one end of the arm a mounted ball to represent the earth is locked into position, as shown, and at the other end a sighting vane is attached. The ball carries a representation of the equator, the tropics, and polar circles. By a pulley arrangement the globe is made to revolve with its axis always pointing in one direction. The sight when brought against the name of any month shows the position of the sun with relation to the earth during that month.

It should be noted that in this model the axis of the earth will preserve a constant direction, but the earth will rotate only once during a revolution. Frictional resistance may prevent the string from turning easily in some cases: if this is found to occur the trouble can be eliminated by using Meccano parts in a similar manner to that of fig. 18 showing the solar and sidereal time model. The diameter of the pulley used must be the same as the support for the base of the stand, which may be held in the hand during the demonstration.

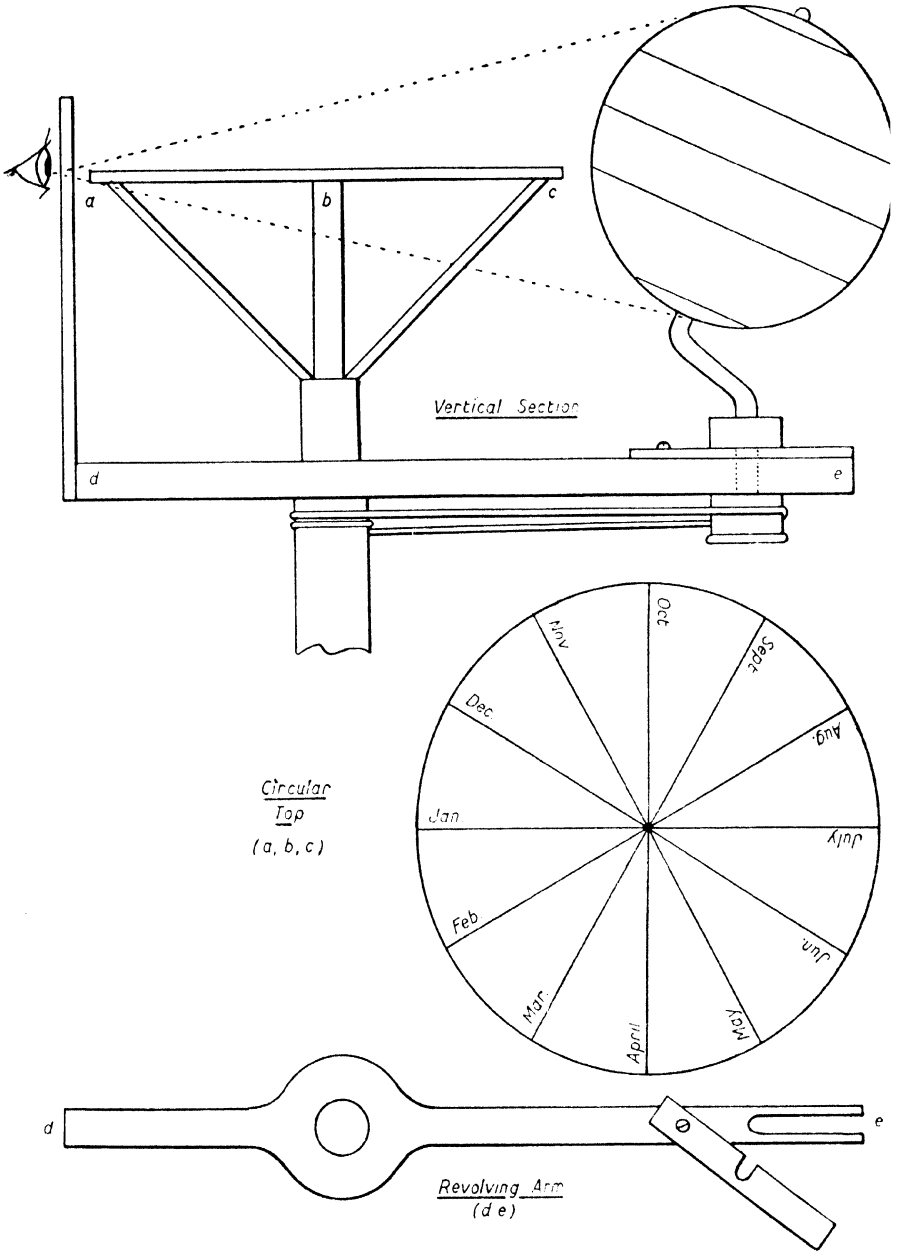


Fig. 6.—The Dissanaike tellurion.

(d) Flat Tellurions

Two examples of this type of model are illustrated. In the first, shown in fig. 7, the direction of the sun's rays are drawn as parallel lines on a rectangular piece of cardboard. The earth is represented by a large circle of cardboard on which the equator, the tropics, and the polar circles are shown as straight lines. Other latitudes of special interest to a class, e.g. London and Dunedin, New Zealand, may be added when desired.

This circle is arranged to turn about a drawing-pin fixed through the central ray from the sun. A sheet of cardboard, or stout blue-tinted cellophane, or a similar transparent substance such as Kodatrace obscures one-half of the earth and is used to indicate that part of the earth which is in shadow.

The seasonal conditions are obtained by turning the circle until either the equator or the tropics receives the sun's rays vertically. Pupils in a class can, of course, easily construct this type of model for themselves and should be encouraged to find the conditions of intervening months; to compare the situations arising in the two hemispheres and to make a clear distinction between astronomical conditions in the Tropical, Temperate, and Polar zones.

The instrument may be adapted for more accurate measurements than the three-dimensional tellurions described, and the actual lengths of day and night for any particular latitude may be calculated. For Dunedin these values may be obtained by drawing a semicircle on the parallel of Dunedin as diameter and producing XY parallel to the axis to cut this semicircle at Z. The semicircle is then divided at Z into the required proportion of day and night.

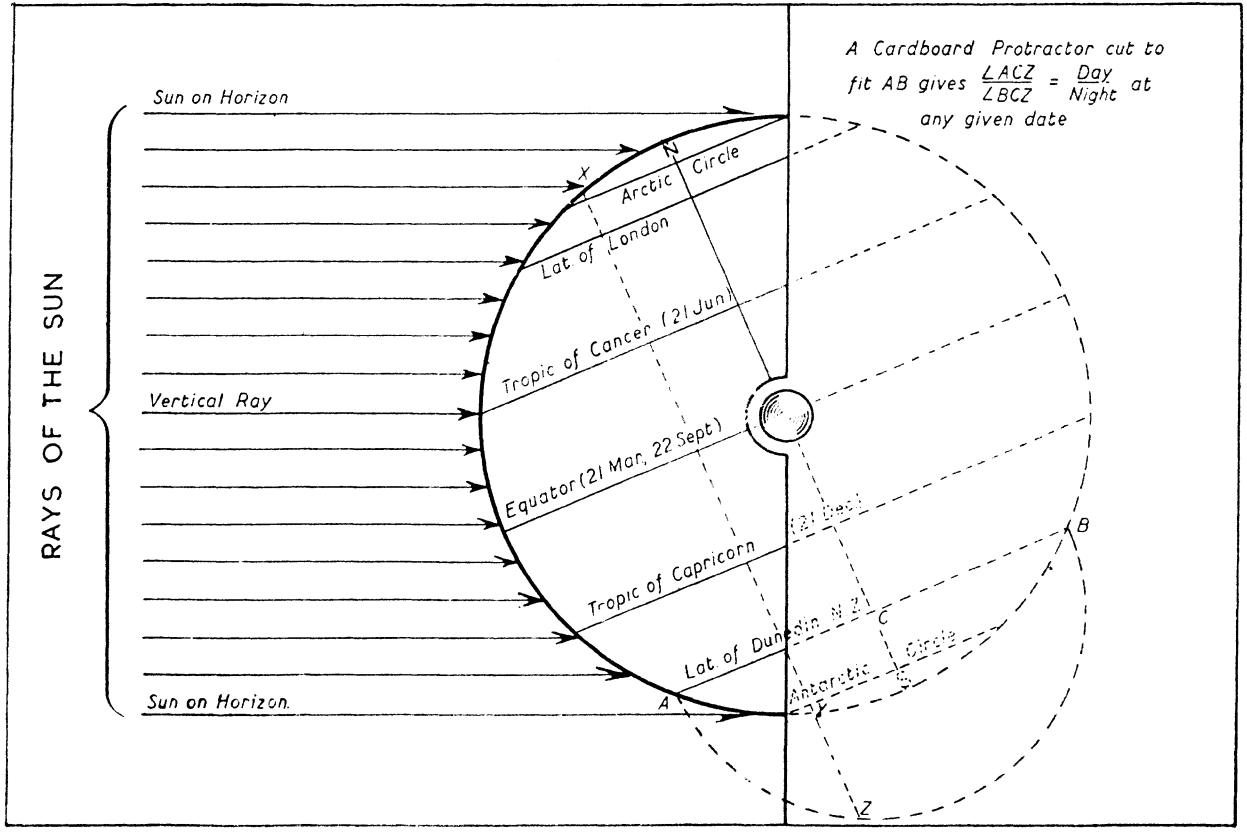


Fig. 7.—A flat tellurion.

One important objection may be directed against the model described and illustrated in fig. 7, and this is that the tilt of the earth's axis is changed so that pupils are likely to forget or become confused with the actual conditions. To meet this objection the model shown in fig. 8 has been devised.

Two equal circles are cut from cardboard: the earth is drawn on the lower one of these and a semicircle, shaped as in fig. 8, is cut on the same scale from the upper. The rays of the sun are also drawn on the upper circle, and a drawing-pin inserted through the centre of both. The seasonal conditions are obtained by turning the upper circle and as this merely involves changing the angle of the rays whilst the earth remains in the same position it meets to some extent the possible objection to fig. 7.

Portions of the upper disk may be cut away to disclose dates marked on the lower disk which come into view when the upper disk is turned. The bottom position should be used for the December situation, as this causes the sun's rays to meet the earth on the opposite side to that shown for 21st June.

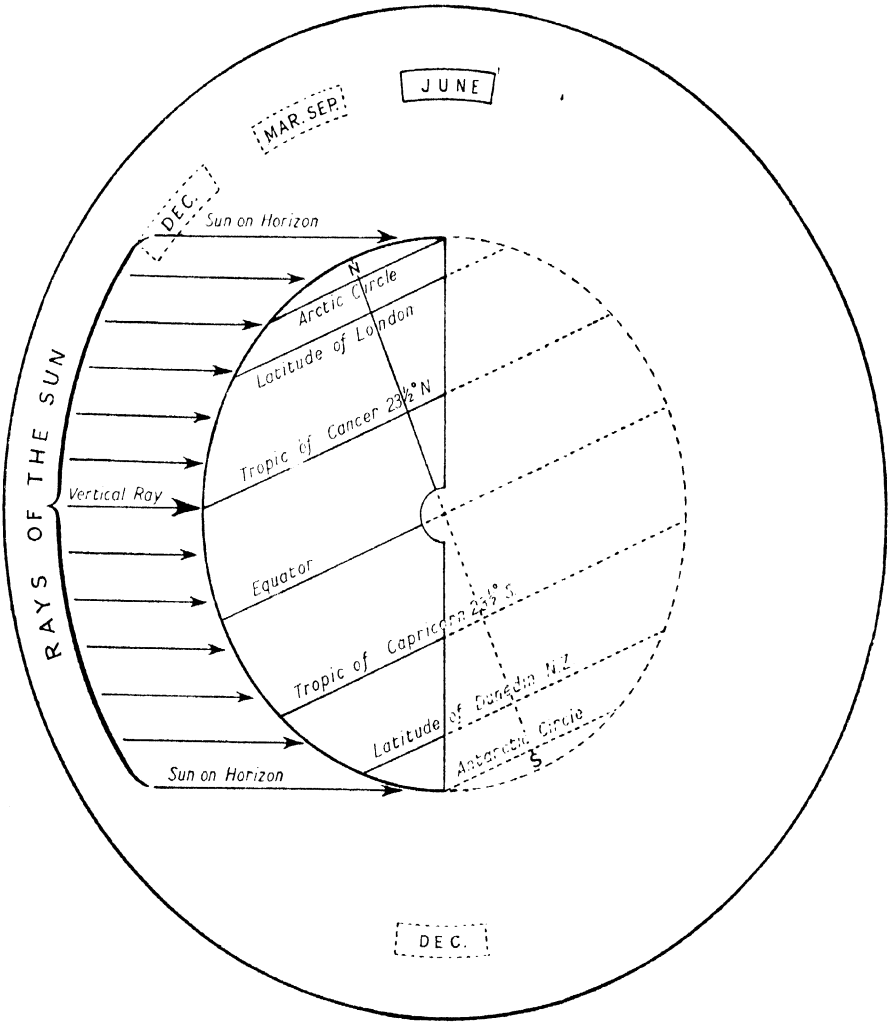


Fig. 8.—A flat tellurion.

4 The Path of the Sun in the Sky at a Given Site

(a) The Glass Dome Method

Various ideas have been put forward to plot the path of the sun in the sky at a particular school site. That indicated in fig. 9 was described by McKay in *Geography*, Vol. XVI. It consists of a hemispherical glass dome similar to the type used to cover artificial wreaths. A small disk of gummed paper is placed in such a position on the dome that its shadow falls within the small circle at the centre of the drawn horizon. It is not difficult for the pupil to realize that a small model of a man placed in that circle would be in the shadow, and consequently the disk on the dome is coincident with the sun in the sky.

The disks should be placed in position at intervals of approximately one hour throughout the day, and the dates chosen should be on or near the solstices and equinoxes. Should part of the day become cloudy, the next day or two could also be used for the experiment as the sun changes its position very slowly, especially near the solstices. Using this method, it will be seen that the disks can be placed in position at any time convenient with other school commitments.

A very open situation is desirable if observations are to be made when the sun is low in the sky, whilst at the summer solstice the observer will need to rise reasonably early. After fixing, the disks should be given a light coat of shellac to protect the gummed surface from rainwater. As McKay points out, the method is capable of further development and, in the hands of the interested and skilled teacher, should develop in a pupil of normal intelligence a clear understanding of the cause and course of the seasons.

(b) The Spary Method

A second method shown in fig. 10 was described by Spary in *The Geographical Teacher*, Vol. XI, Part 3. This is perhaps not quite so suitable for younger pupils as the method already described above, as the observations are not so directly applied to the finished model.

The angle of elevation of the sun is measured at convenient times during the day of observation, and these angles are plotted against time on a graph.

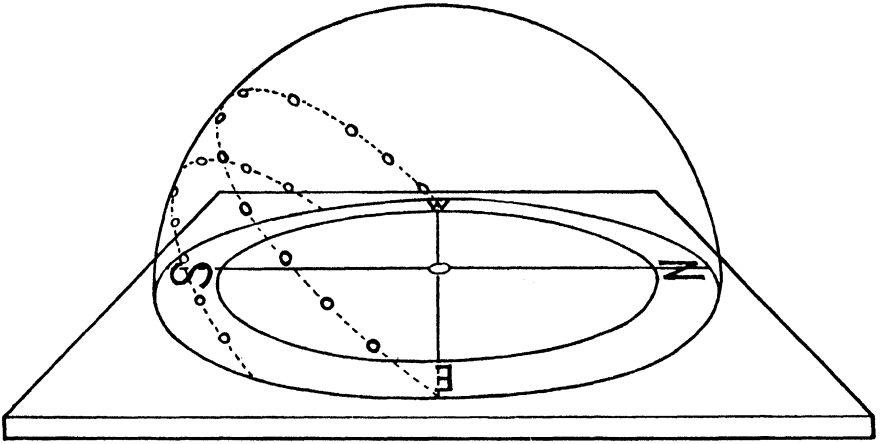


Fig. 9.—The Glass Dome method.

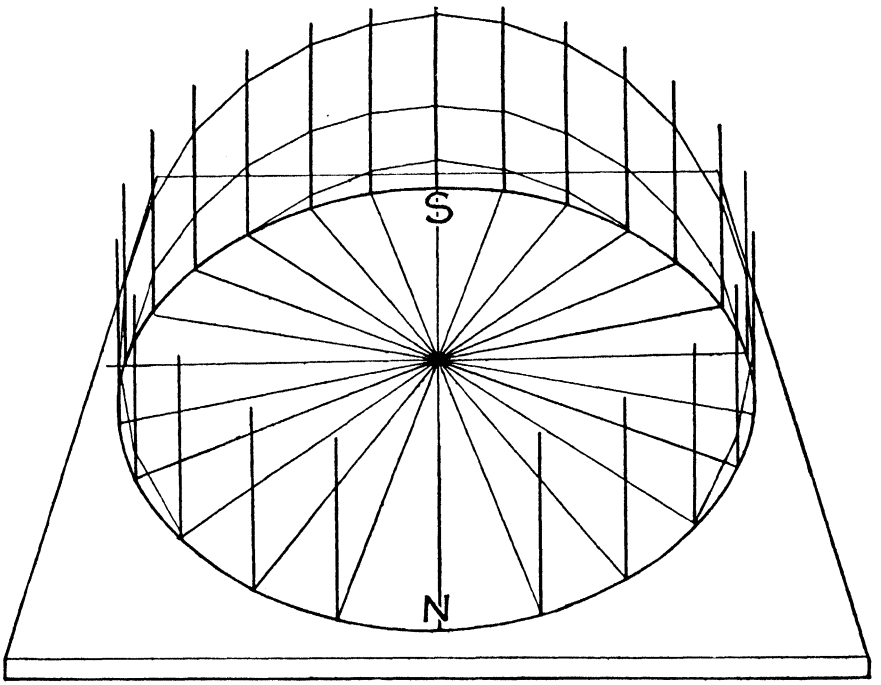


Fig. 10.—The Spary method.

A curve is drawn from which the elevation of the sun may be read at each hour of the day. The model on which these records are to be given permanence consists of a board with an horizon circle around which wooden rods are erected at intervals of 15°. The elevation curve is cut from the graph paper and bent round these rods,[1] a mark being made on each at the point reached by the paper. The paper is removed and a hole bored through each rod at the appropriate mark. Suitable thread is then passed through the holes to give a permanent record of the sun's path. It is suggested that the experiment be repeated on the twenty-first day of each month between the solstices, giving seven records in all. It should be noted that the horizontal distance representing one hour on the graph must be made equal to the distance between the rods.

The method used for measuring the elevation of the sun is immaterial. If no simple mechanical means is available the method proposed by Spary can be adopted. The apparatus, shown in fig. 11, should be self-explanatory. The construction is orientated until the shadow of the protractor is a line along the centre of the baseboard. The wire indicator is then turned by the handle until the shadows of the pointers coincide on the baseboard. The angle of elevation of the sun's rays may now be read on the protractor. This simple instrument can easily be made by the pupils themselves, thus adding interest to the experiment.

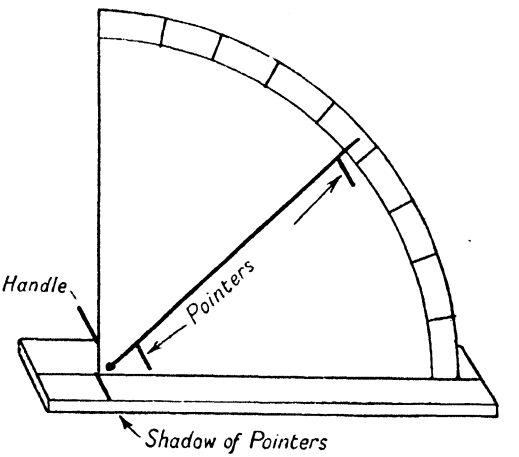


Fig. 11.—Apparatus to measure the elevation of the sun.

[1] As the rods are, of necessity, vertical, greater accuracy results if the graph be one in which the tangent of the angle of elevation of the sun be plotted against time, instead of the actual angle of elevation as suggested by Spary.

5 The Path of the Sun in the Sky at any Latitude

(a) The Sun Arc

A model which can be adjusted to show the arc followed by the sun across the celestial sphere at the solstices and the equinoxes in any latitude is illustrated in fig. 13. Two large annulets are drawn and cut from thick cardboard to the patterns shown in figs. 12 (*a*) and 12 (*b*). One of these is intended to represent the observer's horizon and the other his meridian (actually the arc of the celestial sphere where it is intersected by the plane of the meridian). If the two annulets and path circles are graduated as shown it will be possible to obtain the times and compass directions of sunrise and sunset at the solstices and equinoxes.

Two large circles (each a little smaller than the internal diameters of the annulets) are now cut from stout cardboard. One of these is to represent the plane of the meridian and should be notched and marked as in fig. 12 (*c*). The remaining circle and two similar ones of radius $R \cos 23\frac{1}{2}°$ (where R is the radius of the large circle) are now marked and notched as in figs. 12 (*d*), and 12 (*e*). The three circles should then be interlocked with the meridian. Fine pins or needles pushed through the horizon at the E. and W. points should engage the largest circle to form a spindle.

The assembled model is shown, on a reduced scale, in fig. 13. In using it the spindle should be turned until the largest (central) circle points to the latitude it is desired to investigate. The three circles will then represent the path of the sun across the celestial sphere at the solstices and equinoxes at that latitude. The position of each circle below the horizon represents the night and the instrument in fig. 13 is set for the latitude of London. The short day of the winter solstice (lowest circle), the equality of day and night at the equinoxes (centre circle), and the long day of the summer solstice (upper circle) are apparent at a glance.

The reverse side of the celestial meridian could, with advantage, be graduated in degrees from the horizon: it would then be possible to read the altitude of the noon sun at any given latitude on the dates of the solstices and equinoxes.

The model could be constructed entirely of Perspex which is easily fashioned by means of a fret-saw and bends readily when heated, thus enabling the annulets to be assembled.

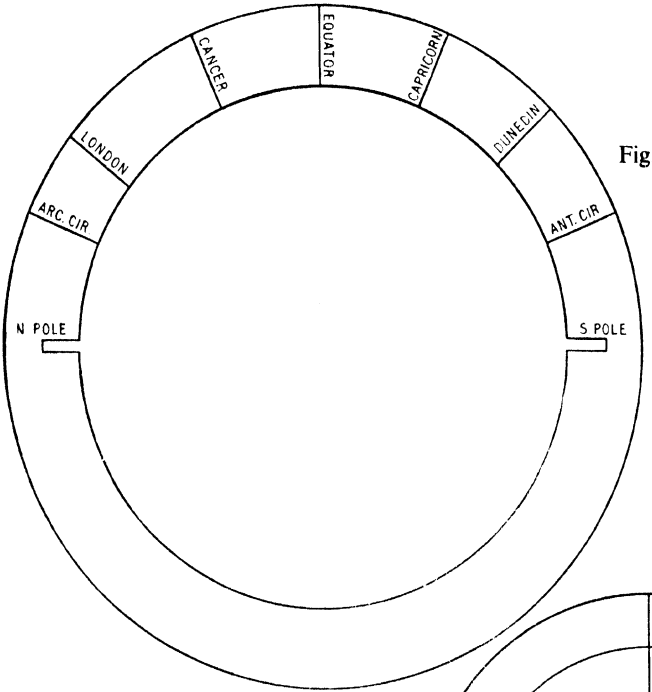


Fig. 12 (*a*)

Fig. 12 (*c*)

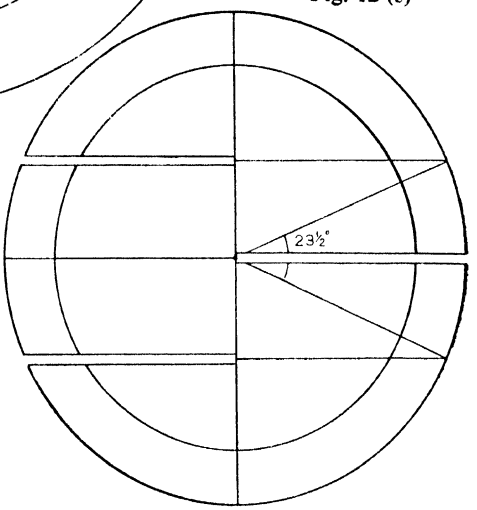
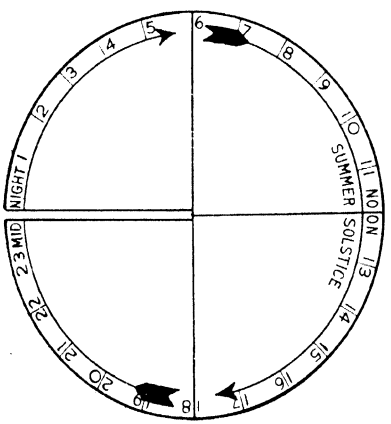


Fig. 12 (*e*)



Figs. 12, 13.—To show the construction of the sun arc.

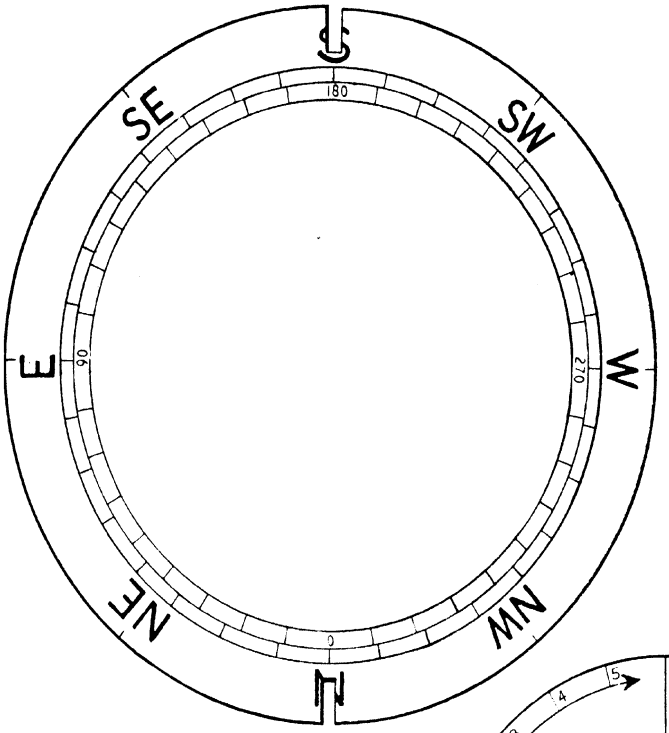


Fig. 12 (*b*)

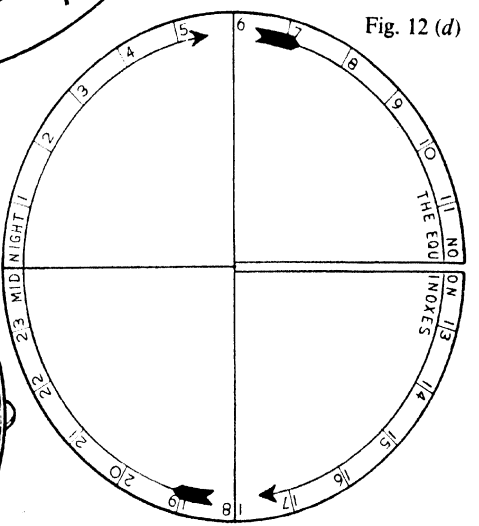


Fig. 12 (*d*)

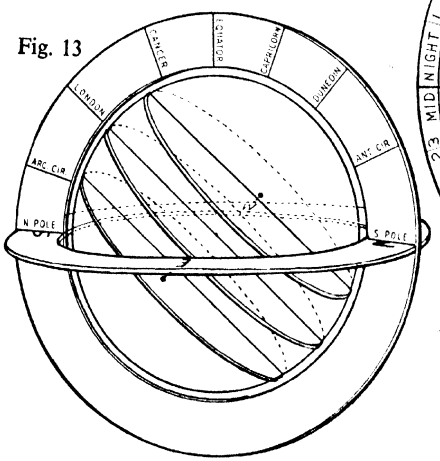


Fig. 13

(b) The Armillary Sphere

This instrument, of great use for rough work in field astronomy, may also be used for sun-path demonstrations. The base and supports can be easily constructed from wood, while the hoops from a drum of preserved fruit will often serve admirably for the horizon and meridian circles. The remaining parts are best constructed from metal, the axis consisting of a Meccano axle: whilst the pointer, which is arranged to turn at the central point in a frictional grip, is made of a strip of zinc or a length of knitting needle. The instrument is shown in fig. 14. The meridian circle represents the arc of the celestial sphere where it is intersected by the plane of the meridian, and the horizon circle similarly represents the arc of the celestial sphere where it is intersected by the horizon plane of the observer. The latter is imagined to be situated at the centre of both circles, whilst for the purposes of the present demonstration the end of the pointer will represent the sun.

The meridian circle can turn in its own plane and must be moved to a position such that the axle makes an angle with the horizon circle equal to the latitude. The axis is designed to turn in two holes bored in the meridian. Thus the axis can be set so that, when rotated by means of the small wheel, the pointer will trace the path of the sun in the sky in a given latitude. When the pointer is at right angles to the axis the path traced is that followed at the equinoxes; for the solstices the pointer must make an angle of $23\frac{1}{2}°$ on either side of the perpendicular to the axis.

The model is adaptable for an approximate solution of many astronomical problems. The path of the sun, moon, or any other celestial body may be shown for any date, provided that the declination of the body on that date be known. Further uses for this model will be found in *Exercises in Cartography* by F. Debenham.

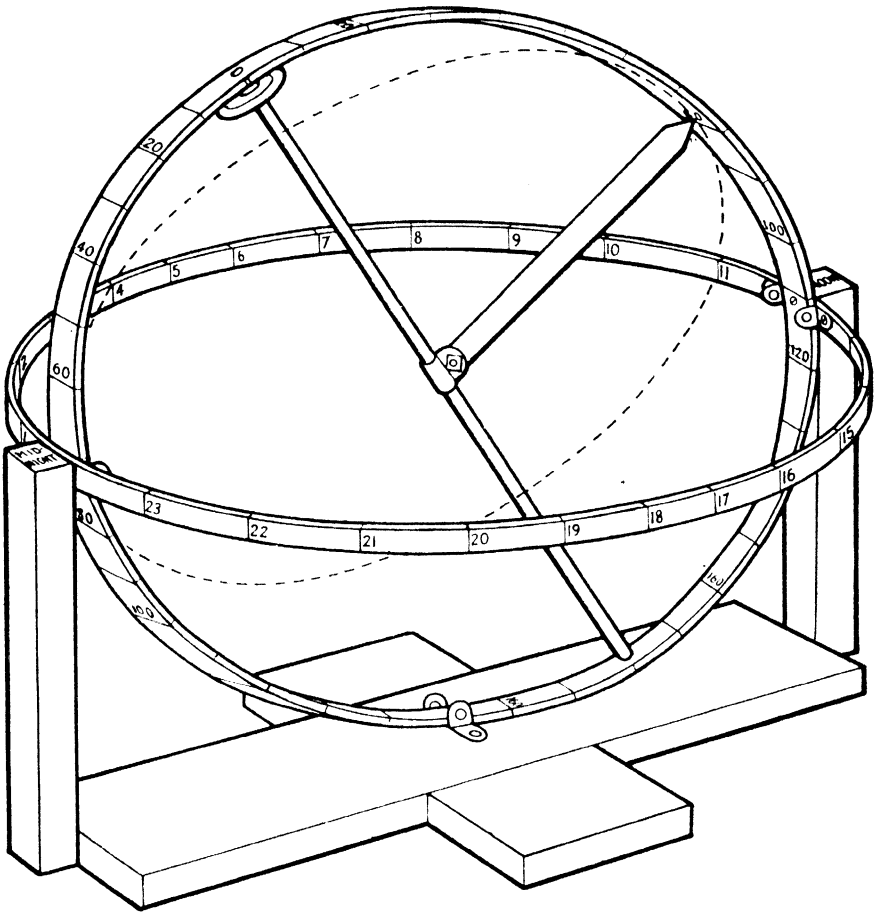


Fig. 14.—The armillary sphere.

(c) Two Dissanaike Models

The two models illustrated in figs. 15 and 16 are based on suggestions by A. W. Dissanaike in *The Geographical Teacher*, Vol. XII, Part 6.

In fig. 15 (*a*) a circle of 9 in. radius is drawn on a suitable board: it is divided by the horizon and the lower half coloured black to represent the night. The upper arc representing the sky and daylight is divided into 180° numbered off 90° each way from the zenith. A wooden or tin frame forming part of a circle equal to the above and extending 23½° away from the centre is graduated as shown in fig. 15 (*b*),[1] and fixed to turn at the centre of the drawn circle.

The frame in use is turned until the arrow points to the same angle north or south of the zenith as is the latitude of the place north or south of the equator. The three arms of the frame will then show the path of the sun at that place at the equinoxes and the solstices. The model may be used to demonstrate the varying length of day and night, the path of the sun in the sky, and the noon altitude of the sun.

Fig. 16 (*a*) shows the second model which consists of a circle of 9 in. radius drawn on a board and coloured black. The equator, tropics, and polar circles are drawn in red. A rectangular frame, inside measurements 9 in. by 18 in. is made as shown in fig. 16 (*b*) and covered with tinted cellophane or transparent paper. This represents the rays of the sun. Fixed to turn about the centre of the drawn circle, it illustrates (*a*) the swinging of the vertical rays of the sun north or south of the equator and (*b*) the varying length of day and night throughout the world at all seasons.

[1] Dissanaike graduated the sides of his frame into twenty-four equal divisions for the purpose of indicating the lengths of day and night at the solstices. This has been corrected in fig. 15 (*b*) by projecting orthogonally twenty-four divisions of 7½° on the semicircle drawn on the side of the frame as diameter.

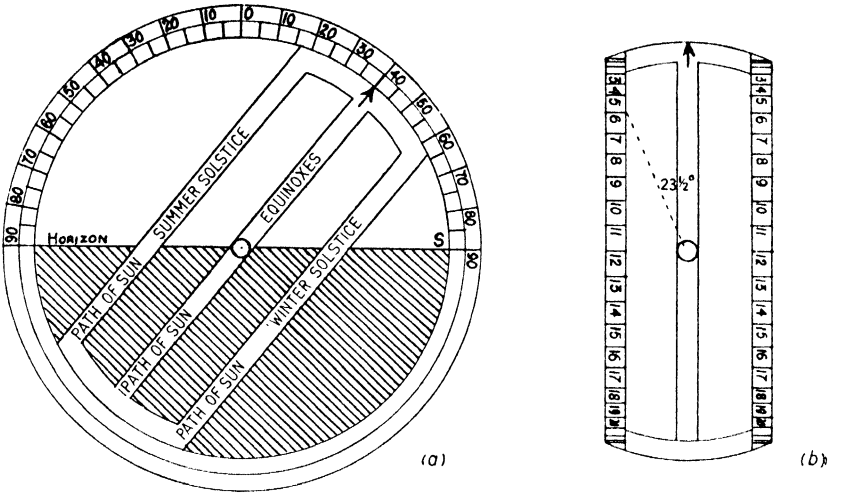

HORIZON
SUMMER SOLSTICE
EQUINOXES
WINTER SOLSTICE
PATH OF SUN
PATH OF SUN
PATH OF SUN
S
23½°
(a)
(b)

Fig. 15

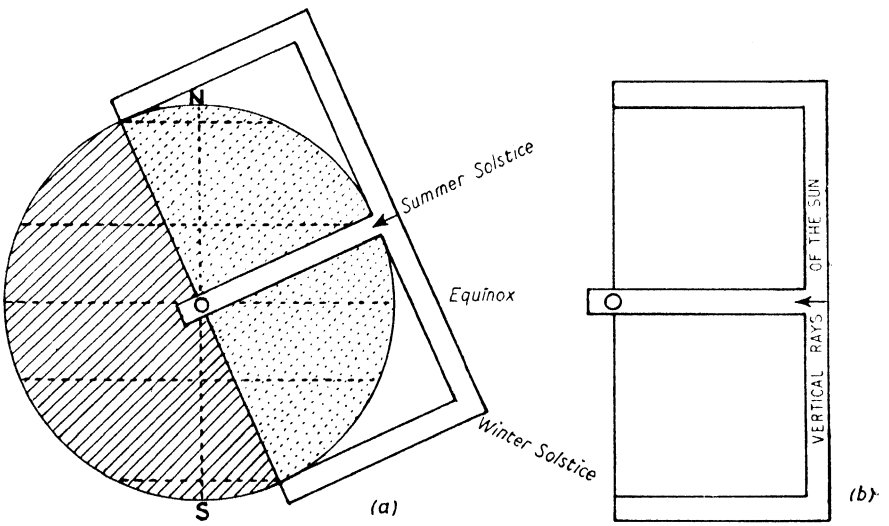

N
S
Summer Solstice
Equinox
Winter Solstice
VERTICAL RAYS OF THE SUN
(a)
(b)

Fig. 16

6 The Problem of Time

The *apparent* or *solar day* is the interval between two successive upper transits of the sun's centre across the same meridian. If the orbit of the earth were a circle, with the sun in the plane of the equator and at the centre of the circle, then this time interval would be a constant. The orbit, however, is not a circle but an ellipse and its plane is inclined to that of the equator. In consequence the intervals between successive transits will vary slightly throughout the year.

To obtain a measure of the day that is uniform, and at the same time corresponds reasonably with the succession of night and day the average length of all the solar days of the year is taken and used as the *mean solar day*. This is the interval to which all clocks are regulated.

The actual difference is not very large and this complication will doubtless be ignored at an elementary stage where it will probably suffice to introduce to the class only the apparent solar day. This day will be defined as the period of time between two successive crossings or transits by the sun of the station's meridian. The crossing is often termed the 'southing of the sun' although of course in the southern hemisphere the sun crosses the meridian to the north of the observer.

The average period between two successive transits of the sun, i.e. the solar day, is then divided into twenty-four hours. It should be emphasized from the outset that time is unaffected by the actual duration of daylight, which, except at the equator, varies in length throughout the year. After a preliminary explanation of the differences in local time, employing a globe and blackboard diagrams, the relevant facts may be clarified by the construction and use of the model described below.

(a) The Longitude-Time Wheel

A large cardboard circle is drawn as in fig. 17 and divided into twenty-four sectors, each occupying 15° of the circle. The radial divisions between these sectors are numbered to represent the twenty-four hours of the solar day, the numbers progressing in counter-clockwise direction. A somewhat smaller circle is similarly divided and cut from cardboard, but in this case the radii

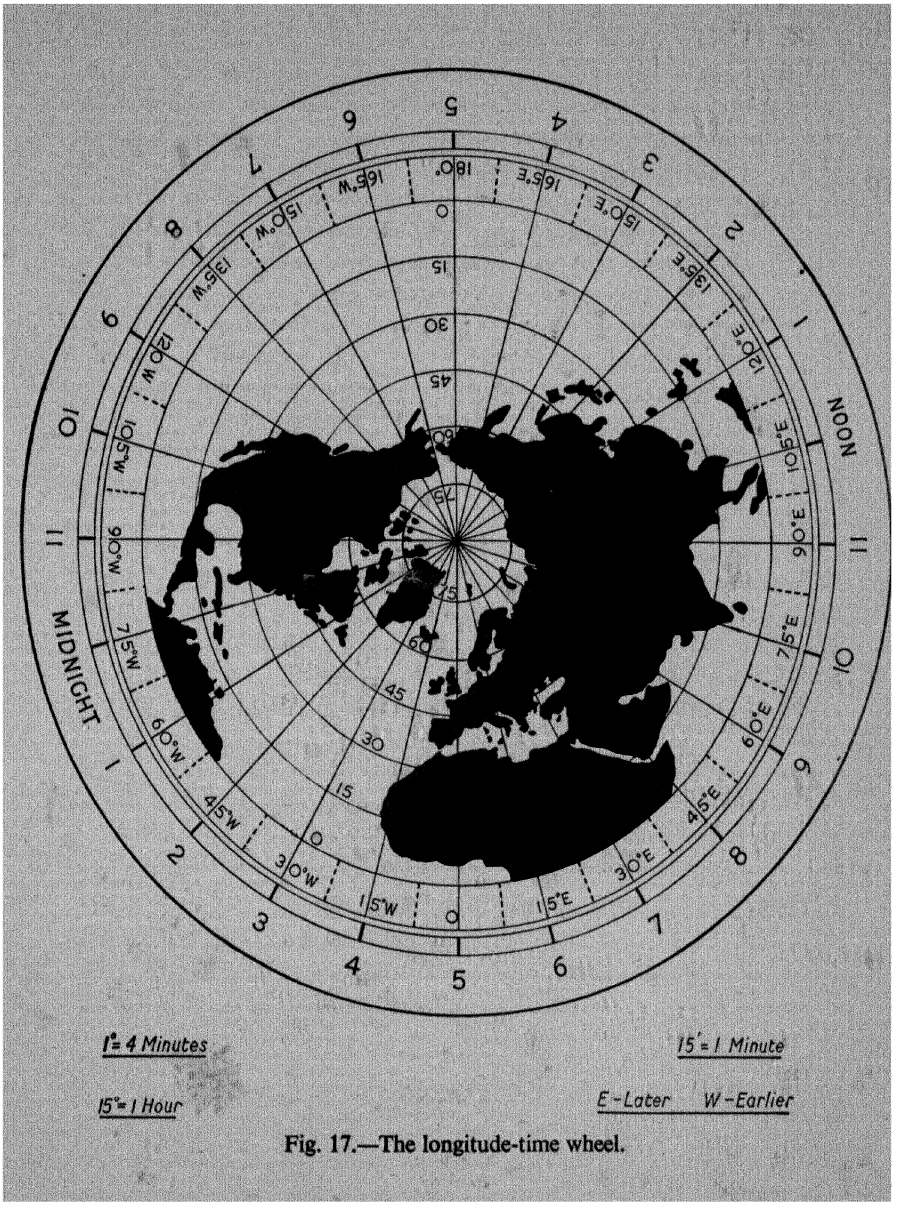


Fig. 17.—The longitude-time wheel.

are numbered to represent the twenty-four prime meridians, the numbers increasing to the east in a counter-clockwise direction and to the west in a clockwise direction from the meridian of Greenwich. This circle is arranged to turn concentrically over the larger one.

When pupils can work to a degree of accuracy represented by one minute of time or fifteen minutes of a degree, time zones may be introduced. The wheel is then divided into twenty-four zones, each taking its time from the central meridian. These zones are indicated in fig. 17 by the pecked lines.

The wheel may now be employed to solve problems such as the following: 'Find the clock time in Damascus 36° 19′ E. when the clocks at Melbourne (145° E.) indicate 3 p.m.' As Melbourne lies in the time zone whose prime meridian is 150° E., turn the wheel until that meridian points to 3 p.m. It should then be clear that the time at 30° E. and therefore throughout the zone containing Damascus is 7 a.m. The wheel in fig. 17 has been drawn for this position.

Each pupil can construct such a wheel for his own use and a large one might be made for class demonstration. The larger class model could, if desired, carry a representation of the earth's surface using the zenithal equidistant projection centred on the north pole. It will probably be found desirable to limit the area shown south of the equator. In addition the rays of the sun might be drawn on the cardboard base parallel to the radius at the noon position.

It may sometimes be difficult to subdivide the circles sufficiently accurately for the current solution of some problems in local time. In such a case the problem will perhaps need working our arithmetically, but the wheel can be used as a rough check and to demonstrate the validity of the arithmetic procedure.

(b) Solar and Sidereal Time

As already stated the solar day is the time between two successive southings of the sun. This period is greater than the time of the earth's rotation which is measured by the successive crossings of a meridian by a star. When a star is used in this way as a fixed mark the interval of time is called a 'sidereal' day.

The difference between these two periods may be readily demonstrated, although not strictly true to scale, by the model shown in fig. 18: this can be built entirely from Meccano parts. The large pulley represents the sun and is fixed to a vertical axle, which is connected, but not rigidly, by a metal strip to a smaller vertical axle on which the smaller pulley representing the earth can turn freely. As the small pulley is made to revolve round the large one it will be rotated by means of the belt in the direction indicated. A small cardboard disk is shown superimposed on the earth pulley: on the disk is drawn a representation of the northern hemisphere based on the zenithal equidistant projection.

In the diagram the earth has been drawn in two positions between which it has rotated once, i.e. these positions represent the interval of a sidereal day. Further rotation is needed before the same point on the earth again faces the sun (i.e. points along the strip of metal joining the centres of the two pulleys). Thus the solar day is demonstrably greater than the sidereal day.

Without elaborate gearing it is not possible to make the model correct to the time scale, for the earth rotates approximately 365 times as fast as it revolves around the sun: consequently the angle between the two positions shown would, to scale, be rather less than 1° which is insufficient for demonstration purposes. The model described, however, will enable the principle to be shown and once this has been grasped it should be easy to proceed by means of a diagram to an explanation of the (approximately) four minutes' difference between the sidereal and solar day.

Note. This model may be adapted to demonstrate the time difference involved between successive high and low tides. In this case the large pulley should represent the earth and might carry a representation of the Northern Hemisphere whilst the small pulley will represent the moon. The connecting belt is removed.

If the pupils are introduced to an explanation of the origin and nature of the tide by means of the equilibrium theory, then periods of high tide will be correlated with times when the moon is vertically overhead. The earth rotates on its axis approximately once in twenty-four hours but the moon is revolving around the earth approximately once every twenty-eight days. In consequence the 'lunar tidal day' is longer than twenty-four hours by an amount equal to about 1/28th of the whole day. That is by the amount of additional time needed before the same earth point is again vertically beneath the moon.

This may be demonstrated with the model by arranging for the small pulley representing the moon to move slowly round the large pulley representing the earth at approximately 1/28th of the angular speed of the large pulley. When one complete rotation of the earth (large pulley) has been made the additional amount of rotation necessary before the same earth point is again beneath the moon will be obvious. The gears needed to give the required ratio would of necessity have to be specially made. The largest would be fixed to the revolving arm but freely turning on the axle of the 'earth' pulley. Above this the smallest would be fixed to the 'earth' pulley. The two engaging gears would be soldered together and free to turn on an axle along the revolving arm.

Should the construction of gears be impracticable the model could be made as follows:

The earth should be represented by a small pulley of radius $\frac{1}{4}$ in., covered by a large cardboard disk, and free to turn at the end of a lengthened Meccano strip, which serves as a revolving arm. The moon should be represented by a large pulley of radius 7 in. rigidly fixed at the other end of the arm, and with a small cardboard disk to represent its size. The belt should cross as in fig. 18.

It can also be shown with the model that in the period of the lunar tidal day, which comes to about 24 hours and 50 minutes, there will have been two high tides and two low tides such that the interval between successive high tides emerges as 12 hours and 25 minutes.

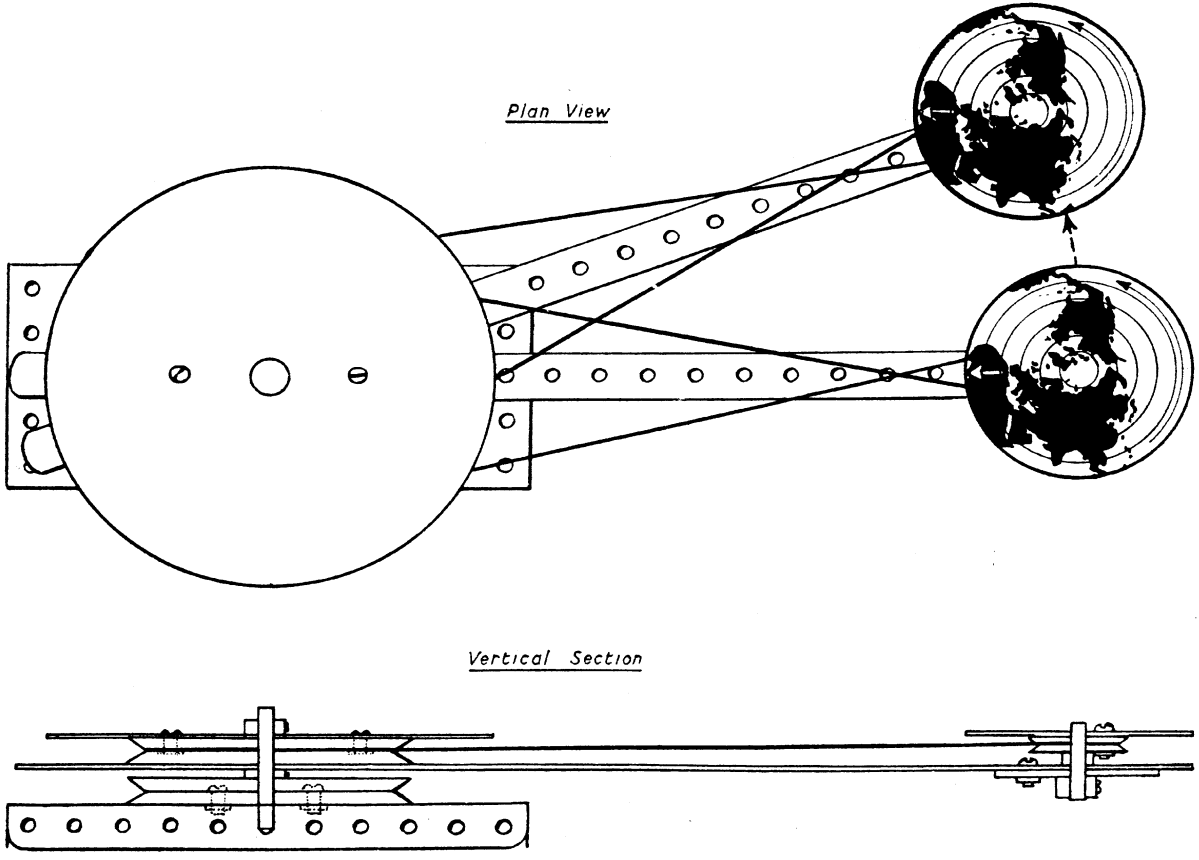


Fig. 18.—Solar and sidereal time apparatus.

(c) Sundials

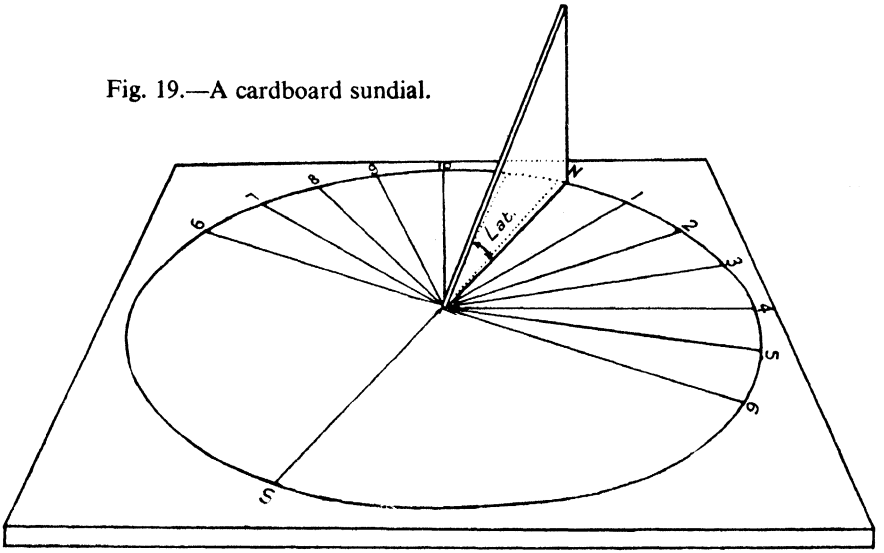
Once the pupil has a clear grasp of the principle of sun paths the step to using the sun directly for measuring time is simple. Any apparatus constructed with this object in view is termed a sundial and two forms are illustrated from the considerable number which exist.

(i) A CARDBOARD SUNDIAL. The vane in fig. 19 can be made of thin wood, tin or Perspex and the base angle should equal the latitude in which it is to be used. The shadow of the vane on the base will be such that the hypotenuse indicates the time. A circle is drawn on the wooden base and a diameter is chosen as the N.–S. line and the vane erected on this line. This line will represent midday, and the position of the hour lines before and after this are obtained from the formula $\tan x = \sin l \,.\, \tan h$, where l is the latitude, h is the hour angle of the sun, and x is the required division along the dial corresponding to the hour angle h. The divisions can of course also be obtained experimentally.

The apparatus is erected on a pedestal with the N.–S. line correctly orientated on the meridian at the particular point. If the meridian is determined magnetically some correction for the variation will be necessary. It may be noted that this type of sundial is not very suitable for low latitudes.

(ii) A TUBULAR SUNDIAL. A variant of the horizontal dial which may be used in any latitude is shown in fig. 20. In this the axis of the glass cylinder makes an angle with the base equal to the latitude and lies in the plane of the meridian. In the model illustrated a knitting needle passes along the axis of the cylinder through two cork stoppers and is held in position by a cork which must be securely fixed to the base. A support for the upper end of the needle is desirable but must be arranged on the north side of the cylinder. Provided that the glass is not too thick and that the needle is centrally positioned, the shadow of the needle on the paper indicator affixed to the cylinder will give a reasonably accurate indication of the time. The indicator should consist of a strip of semi-transparent paper which may be experimentally divided into twelve hourly parts numbered as shown.

Fig. 19.—A cardboard sundial.



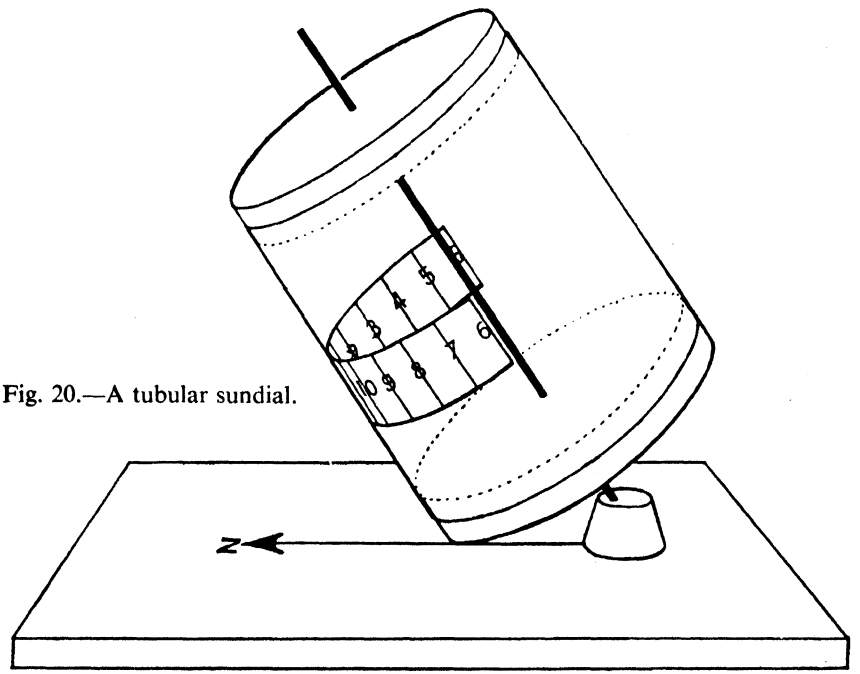


Fig. 20.—A tubular sundial.

7 The Phases of the Moon

(a) A Flat Model

An easily constructed model to demonstrate the phases of the moon is shown in fig. 22. It consists of two large equal disks of cardboard which can rotate about a common centre. On the upper disk the halves of the moon facing the sun are cut out thus disclosing the surface of the disk below. On the latter, shown greatly reduced in fig. 21, is drawn a circle to represent the moon at the same distance from the earth as those on the upper disk: the circle, however, is made slightly larger than those on the upper disk and has the side which would be invisible from the earth shaded. A tab is attached to the lower disk enabling it to be rotated. On turning the lower disk until the moon drawn on it coincides with one of the positions on the upper disk it will be at once apparent how much of the bright surface can be seen from the earth.

The model may be further extended in two ways. On the one hand the phases of the moon may be shown on an inner circle on the upper disk. These are drawn on a scale such that tangents from the earth to them will also be tangential to the actual figures of the moon on the outer circle. In this way it is easy to see that they represent the phases as seen from the earth. If this be done it is preferable to hang the model up by the tab (where this is opposite to the circle on the lower disk as in fig. 21) so that on turning the upper disk each phase comes uppermost and shows the shape of the bright portion exactly as it would be seen.

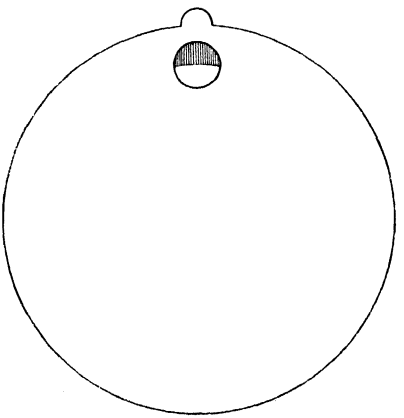


Fig. 21

Secondly, a T-shaped indicator may be placed as shown to turn over the upper disk; and so utilized to indicate the rising, southing, and setting of the moon in each phase. Owing to (*a*) the eccentricity of the moon's orbit and (*b*) the fact that only one meridian is exactly opposite the moon at the moment of each phase, the times will of course only be approximate. The diagram has been drawn for a broad crescent phase when the approximate times would be: rising 10.00 hours, southing 16.00 hours, and setting 22.00 hours.

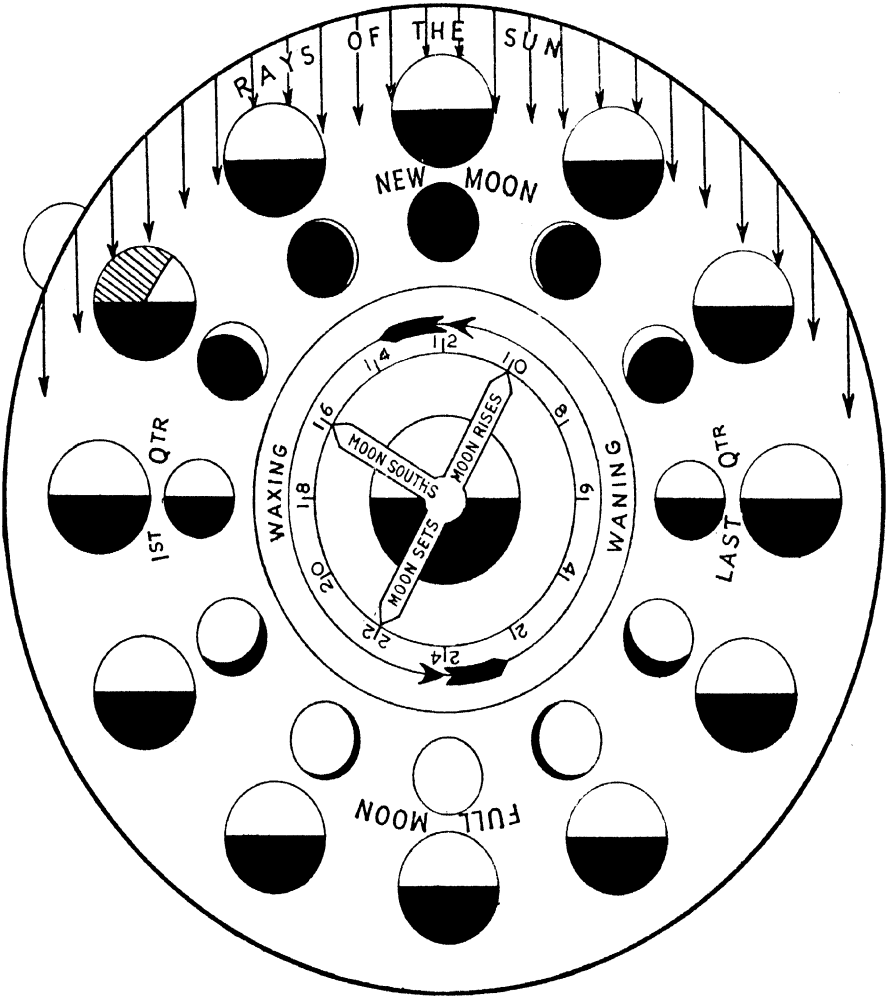


Fig. 22.—The phases of the moon, a flat model.

(b) A Meccano Model

This type of model will probably have a great appeal to more junior audiences than the flat model previously described. On the other hand the flat model can easily be constructed individually by all members of the class. The Meccano model might then be used for class demonstration and as a useful adjunct to the flat model.

In the model illustrated (fig. 23) a tennis ball, stripped of its cover, was used for the moon, whilst a slightly larger ball was used for the earth. One side of the latter should be blackened to represent night and the *opposite* side of the moon shaded or blackened to indicate that it is invisible from the earth. The facing halves of each ball may then be whitened. A hemisphere somewhat larger than the tennis ball and concentric with it is used to show the side of the moon which receives no solar illumination.

The parts are assembled as indicated in fig. 23, the cord being passed once round each pulley to prevent slipping.

Movement of the apparatus on the freely running wheel will now simulate the movement of the moon around the earth and the extent to which the moon will be visible from the earth at the quarters and intervening periods will be clearly demonstrated.

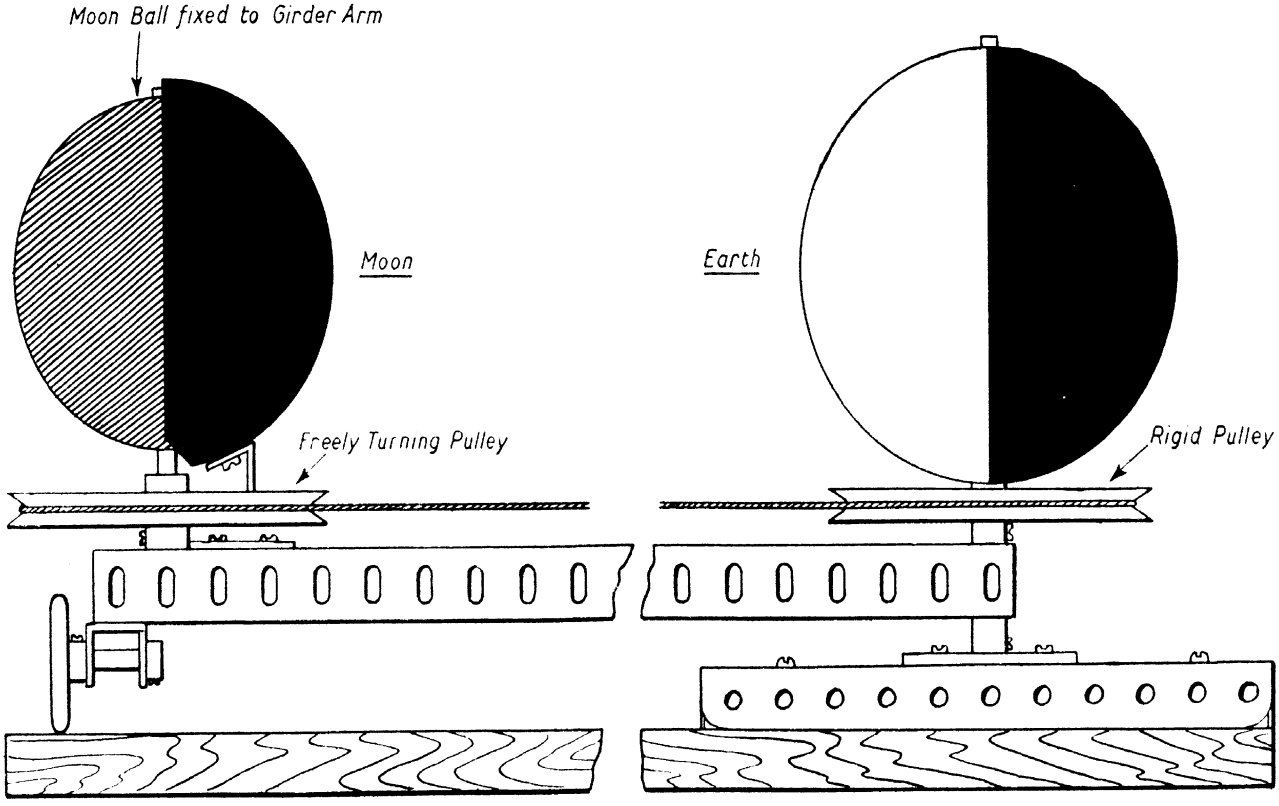


Fig. 23.—The phases of the moon, a Meccano model.

8 A Simple Gnomon

The apparatus shown in fig. 24 consists of a long board about 6 in. wide with, at one end, a vertical wooden column surmounted by a decapitated nail or portion of a knitting needle. Parts of equidistant concentric circles are drawn as indicated with the base of the vertical column as centre of the circles.

USE OF THE GNOMON. Direction may be obtained by placing the instrument in a roughly N.–S. direction. The shadow of the nail will fall on the board towards noon and, when the tip of this shadow touches one of the circles, the point should be marked (*A*). Observing the shadow a little after noon it will eventually touch the same circle again at (*B*). The line joining the mid-point of *AB* to the nail lies in a N.–S. direction.

When the gnomon has been correctly orientated it may be used for determining latitude and measuring the altitude of the noonday sun. When the shadow of the nail lies on the N.–S. line its tip should be marked. The angle of the elevation of the top of the nail, which can be estimated by protractor, is then the required altitude of the sun. An alternative method would be to arrange for the tip of the nail to be 5 in. above the board. The N.–S. line on the board should then be graduated from the foot of the column, the first 5 in. being numbered 1; then each half inch represents the first decimal place and each twentieth of an inch the second decimal place. The position of the tip of the shadow represents the cotangent of the required angle to two decimal places and the angle can then be determined from trigonometrical tables.

The latitude of the gnomon is the complement of the altitude of the sun determined in the foregoing manner, plus the declination of the sun if north of the equator, or minus the declination of the sun if south of the equator, on the day of the observation.

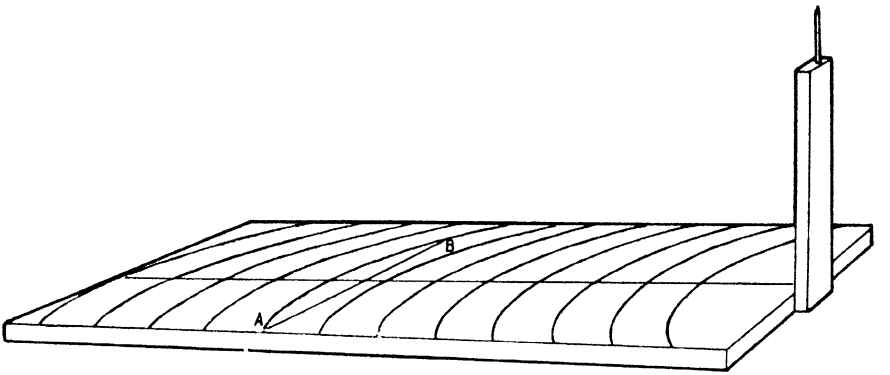


Fig. 24.—A simple gnomon.

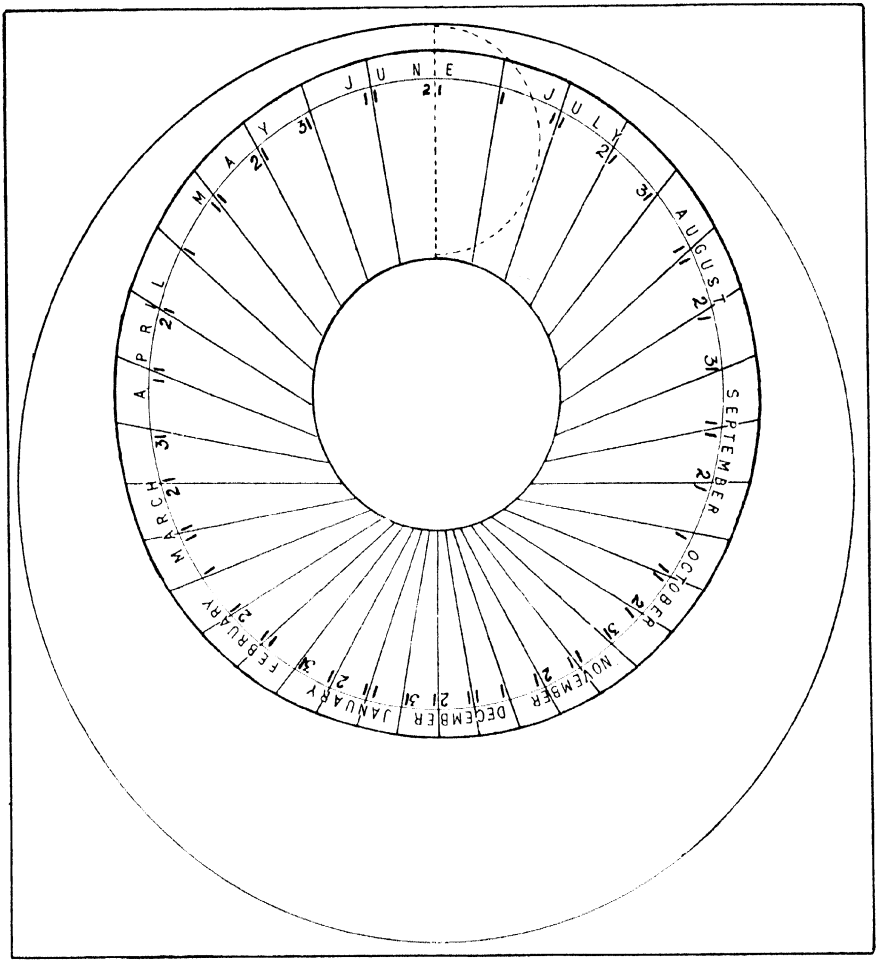
9 The Ecliptic

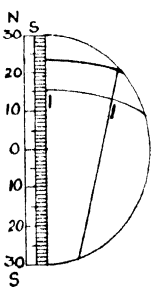
Latitude may be found by observation of the maximum altitude of the sun on any day provided that the latitude where the sun's rays are vertical on that day is also known. This information may be obtained from astronomical tables, but lacking these, resort may be made to the model illustrated in fig. 25.

Here the ecliptic has been drawn on a sheet of cardboard on the equidistant projection. A scale of 1 cm. to 10° is recommended for a demonstration model. It is not necessary to draw the whole projection but the points 66½° and 90° N. must be determined. A circle of radius 9 cm. is first drawn centred on 66½° N. and afterwards corrected by the method explained in the model of the heavens (p. 44) to measure 180° across the pole. The meridians for intervals of 10° are drawn and finished off with the date as shown. A circle is drawn centred on the pole to enclose this, cut out, and arranged to turn about its centre on a stout cardboard base.

A large sheet of thin cardboard is placed over all and from it is cut a portion, which may be conveniently arranged semicircular as indicated by the dotted line. The ecliptic must always appear in this semicircle as the disk is turned. The straight edge of the semicircle should be graduated in cm. and mm. in such position that on 21st June the ecliptic cuts it at 23½° N. By turning the disk round the position of the ecliptic may be read, at any of the dates shown, to the nearest degree. Thus the declination of the sun may be determined approximately on any day of the year.

Note. The model may, if desired, be adapted to give the actual elevation of the sun in any latitude on any date. In this case a much larger semicircle should be cut from the cover and graduated in such a manner that the position shown as 23½° should read 47° when it will give the conditions experienced at the Arctic Circle. By moving the cover down 1 cm. the conditions at 76½° will be represented, and so on. The graduations will be similarly numbered to the smaller semicircle shown but will naturally cover a wider range.





Detail of Half Circle

Cut out of Cover

Fig. 25.—The ecliptic.

10 A Model of the Heavens

The model shown in fig. 26 is designed to show the sky as seen by an observer at 60° N. The graticule of the polar stereographic projection between 30° S. and 90° N. is drawn on cardboard and cut out. At least the constellations Ursa Major and Orion should be drawn upon it, also the ecliptic or path of the sun across the sky during the year. The stereographic projection is especially useful here for the ecliptic and horizon are both circles easy to draw. The former has a diameter equal to the distance between $23\frac{1}{2}$° N. and $23\frac{1}{2}$° S. on the graticule.

The cut-out projection should be fixed to a stout cardboard backing in such a way as to turn about the pole. The front of the model consists of a piece of cardboard with a circle of diameter equal to the distance between 30° N. and 30° S. on the projection measured across the pole. This represents the horizon and in use should be placed as shown in fig. 26. Around the horizon are indicated the months of the year, the time of day, and points of the compass. The part of the disk hidden from view is shown by dotted lines.

The Use of the Model

LATITUDE AND DIRECTION. For both these the Pole Star is located by means of the Great Bear but, as this is a circumpolar constellation, it is not easy to recognize it in every position. By turning the disk until the thickened meridian points to the required month the map, as viewed in an upright position, will show the stars as seen at 8 p.m. on the 21st day of that month. Thus, in the position shown, the Great Bear is as seen by an observer looking north at 8 p.m. on 21st November. This hour is chosen as being suitable for most observation work. For every two hours later the months should be put back one, and for every two hours earlier should be correspondingly advanced: thus the position shown would occur at 6 p.m. on 21st December, 4 p.m. on 21st January, 10 p.m. on 21st October, and 12 p.m. on 21st September.

THE APPARENT MOVEMENT OF THE SUN. By observing the movement across the open circle (i.e. the sky) of the appropriate black dot representing the sun in a given month, the time and compass bearing of sunrise and sunset, distance below the horizon at midnight or above at midday, can easily be obtained. Thus in the diagram the sun on 21st September is shown 40° below the horizon on the north and if the disk is turned (anticlockwise) it will rise

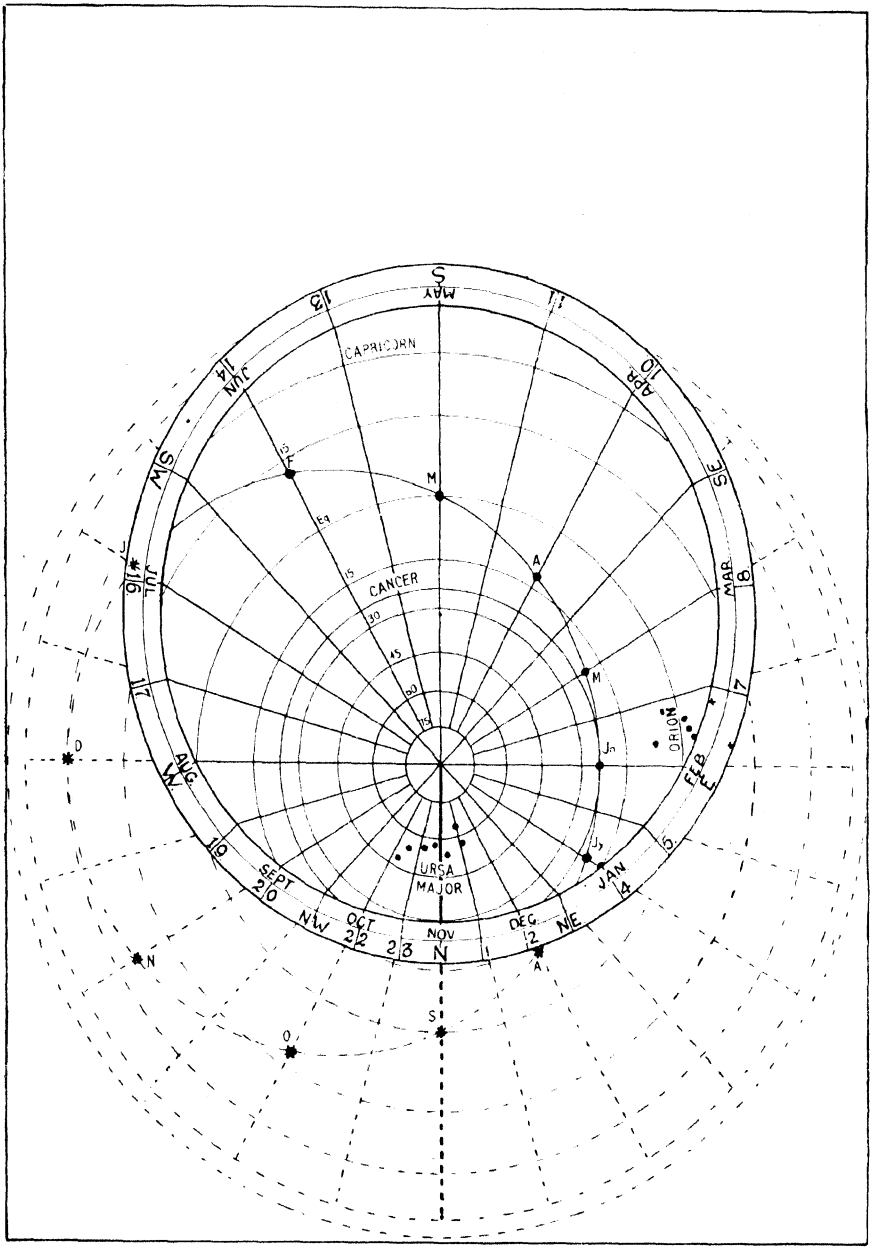


Fig. 26.—A model of the heavens based on the stereographic projection.

in the east at 6.00 hours, and set in the west at 18.00 hours, ascending to 30° above the horizon in the south at midday.

Many other points may also be demonstrated, e.g. the reason why some stars (the Great Bear) never set whilst others (Orion) do, the fact that no star beyond 40° S. is ever visible in the south of England, the determination of latitude by the two meridian altitudes of a circumpolar star, and the ability to recognize the larger stars and constellations at any time by marking their positions on the model.

An alternative model may be made on the polar equidistant projection and this is shown in fig. 27. The projection is easy to draw and a meridional scale of 1 cm. to 10° is suitable. The ecliptic and the horizon are not circular on this projection but circles of 90° radius (9 cm.) should first be drawn, one on the projection centred at 66½° N., the other on the blank cardboard which is to form the front of the model and centred at the spot where the parallel of 50° N. will appear on the disk below. The disk should be redrawn in position on this circle when it will be found that meridional distances across the circle are not exactly 180° or 18 cm. A strip of thick paper with two marks 18 cm. apart and smaller divisions near them to help should be placed symmetrically on each meridian in turn and the points which are 18 cm. apart are then marked. By joining up these points on all meridians the horizon may be correctly drawn. The process is then repeated on the projection for the ecliptic.

This projection is useful as the pivot may be moved 1 cm. upwards or downwards and will then approximately represent the conditions in a latitude 10° higher or lower. The representation is only approximate because the shape of the horizon varies slightly with latitude, becoming more nearly circular in high latitudes. The model may be finished off with the months, times, and points of the compass as shown in fig. 26.

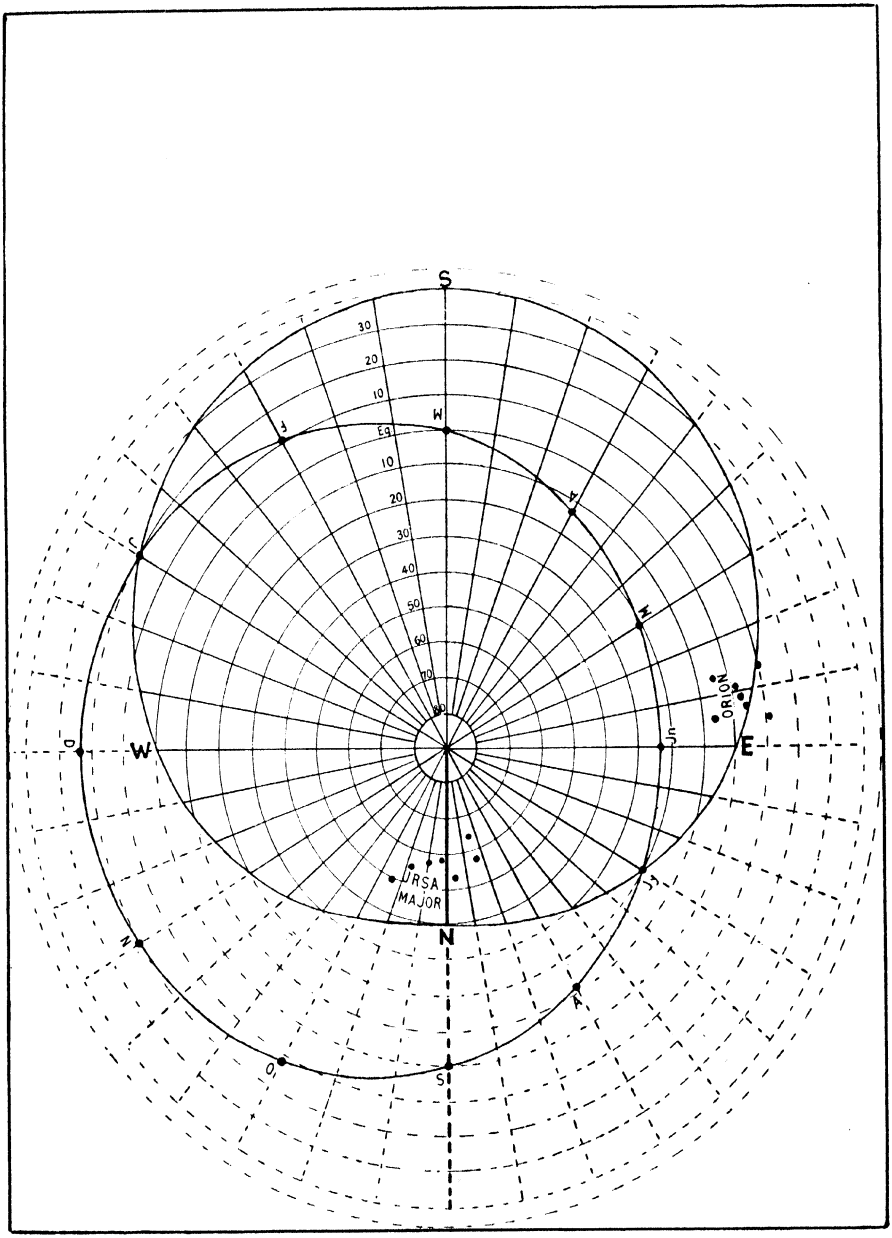


Fig. 27.—A model of the heavens based on the polar equidistant projection.

SECTION B

LAND FORMS

11 A Rock Garden

THERE is a growing tendency among teachers to illustrate their geography lessons with actual examples of the objects, commodities, etc., under consideration. Not the least important in this connexion are the common rocks which make up our countryside. The town dweller will be at a serious disadvantage here for he rarely sees locally any natural rock exposures: but his country brother is often little better off for even he may only be directly acquainted with two or three different types of rock at the most. Examples in the classroom are hence of great value when the fundamentals of physical geography are being taught.

But the teacher may occasionally meet with the criticism that the rocks in the field appear quite different from the type specimens seen in the classroom. This is largely due to the comparison which is being made between the freshly cut, unweathered laboratory specimen used for classroom teaching, and the natural weathered rocks which one will always meet in the field. Unless a geologist's hammer be carried so that a fresh unweathered face can be obtained, identification will naturally prove difficult to the beginner.

A solution may in part be provided for this problem by the construction of a rock garden on the school premises. If the school is fortunate enough to possess grounds with gardens, a word with the gardener will doubtless soon produce willing co-operation once the idea is explained.

The basis for the rock garden will be a representative collection of fairly large specimens of the more common rocks. These will be left exposed to the atmosphere and will eventually weather down to a natural appearance which, of course, can be contrasted with the freshly cut laboratory hand specimens as and when desired. Suitable plants, e.g. rockery and alpine types, can be added to the 'garden', but plants which may tend to obliterate the rocks by

growth should be avoided. The rock specimens should all be labelled and here inscriptions on metal are advisable as these labels will also be exposed to weathering. The name punching machines often found on railway stations may be useful for this job.

Building up the collection may appear a little formidable at first but this is not really so very difficult. There are three main sources of supply. First, the pupils themselves can be impressed into collecting suitable local specimens, whilst a much wider net can be cast annually as a result of summer holiday movements. Requests for help to senior forms will from time to time cover new areas and enable further specimens to be obtained. The student should be instructed carefully in collecting beforehand however, and asked to provide exact details of the location of any specimen so that this can be checked against the geological map and the correct identification established. Additions to the collection obtained in this way might be marked with the donor's name. Once this idea catches on, a fairly regular supply of new specimens would doubtless be assured.

Secondly, for more difficult specimens, a local or county museum might be able to help with surplus material, whilst thirdly, if both these sources fail, recourse can then be had to a dealer in geological specimens (e.g. Thomas Murby & Co., 40 Museum Street, London, W.C.1).

In the majority of cases a true rockery distribution of the specimens will suffice, but if the subject is treated systematically, and perhaps at an advanced level for sixth-form work, then the rock specimens can also be laid out systematically to suit the method of teaching.

We have suggested a list of the more common rocks with which the geographer might be acquainted hereinafter: this should not be regarded as exhaustive, nor in many cases are all the examples necessary. Clearly each rock garden must be planned to the level of teaching, local requirements, etc., and each teacher should select according to his needs.

Common Rocks

We may broadly divide the common rocks into three categories according to their origin: further subdivision being made then in relation to their composition. The three main groups are firstly the *Sedimentary* rocks, comprising as the name suggests those rocks which have been laid down as

sediments either by air or water: secondly, the *Igneous* rocks which have been formed by cooling from a molten condition and are hence largely crystalline: thirdly, the *Metamorphic* rocks which are rocks of either sedimentary or igneous origin which have been subjected to great pressure and heat, and have in consequence had many of their characteristics altered.

SEDIMENTARY ROCKS. These rocks which have been deposited by water or air usually have a very definite structure and are of great importance to the geographer. The geologist can determine their age from the fossil content or the order of superposition of the beds. The rocks may be of any order of compactness and it should be clear that age and hardness are in no way related. We may subdivide this group into three major categories—clays, sandstones, and limestones.

Clays. A clay is impervious to water and readily eroded by water action. When examined closely it will be found to consist of finely divided material which is actually largely mineral and containing much aluminium silicate. Clay soils may be heavy and difficult to work when very dry or very wet, but they are usually very fertile if sufficient lime is present. They usually form lowlands if in juxtaposition with other rocks. There are many types of clay and some common examples include:

Brick clay. This is a clay with some sand and iron oxide in it. Useful for making bricks as it is fusible.

Gault clay. A purer clay, fairly homogeneous, usually blue in colour and originally laid down in deep water.

Kaolin. A very pure white clay derived from granite and valuable for making pottery.

Red marl. Is a clay with a considerable proportion of lime and iron. Very common in the Midlands of England.

Shale. Is a hardened clay and has many of the characteristics of clay but in addition is finely laminated parallel to the bedding.

Sandstones. These rocks are very common and easy to recognize in the field. They have been laid down either by wind or water and are usually finely bedded although occasionally thicker and more massive bedding occurs. The chief constituents are quartz grains cemented together with various other minerals, e.g. calcium carbonate, iron, silica, etc. Sandstones may assume a great variety of colours according to the cementing material. They are resistant to chemical erosion but may not stand up to

mechanical erosion if the cementing agent is weak. Varieties suitable for a rock garden might include:

Flagstones. Sandstones which have a definite and pronounced cleavage which makes them useful as slabs.

Glauconitic sandstone. A type of sandstone which is coloured green by small grains of the mineral glauconite.

Freestone. A sandstone which has no definite cleavage and can be cut up in any direction.

Millstone grit. A coarse type of sandstone very important in northern England. Originally a deltaic deposit.

Limestones. In this group are many rocks which although they may vary in appearance are all characterized by a high content of calcium carbonate. In contrast to many other rocks they are often resistant to mechanical erosion, but soon succumb to chemical erosion when water containing carbon dioxide or other acids flows across the rock. The relief effect varies with the different types but most limestones are upstanding in relation to neighbouring rocks. The more important divisions include:

Chalk. A common form of limestone in southern England. Fairly pure, very porous and gives a well-known rounded relief.

Oolite. Limestone made up of small globular grains. Important in central England, much used for building.

Silurian limestone. A very old limestone largely made up of fossils.

Carboniferous limestone. Very important in the Peak District. A hard rock but very soluble, hence underground drainage.

Magnesian limestone. A limestone altered by chemical processes. Often called dolomite. A very hard rock.

Kentish rag. Rag describes consolidated limey rocks in more recent formations. This is a very resistant rock.

An important associate of Chalk is *Flint.* *Chert* is a similar material found in certain older rocks. Both are hard and consist of amorphous silica which occurs in the form of nodules or layers.

IGNEOUS ROCKS. These rocks are completely crystalline having solidified out from the molten condition. They are usually very resistant to weathering by normal processes but may sometimes break down rapidly under chemical attack. The geologist may classify these rocks according to the depth at

which they crystallized (plutonic, deep; hypabyssal, medium; and volcanic surface) or according to the amount of silica contained in them (acid, a high percentage; basic, a low percentage). Usually the more acid a rock, the more resistant it is to weathering and the soils derived will be poorer. Once again there are numerous kinds of igneous rock but the following are the commonest producing landscape forms and hence of importance to the geographer:

Granite. A rock composed of felspar, quartz, and mica. Important in south-west England. Resistant to erosion. A useful building stone but giving poor soils.

Rhyolite. An acid lava containing many large crystals of quartz with a matrix of minute needles of felspar.

Obsidian. An acid lava in which solidification took place so quickly that crystals were unable to form. Resembles brown, black or red glass in appearance.

Pumice. Really obsidian in a frothy state. Structure due to cooling occurring when the material was full of water vapour and gases.

Trachyte. A grey crystalline rock important in Scotland. Has a flow structure with occasional large crystals.

Dolerite. A basic rock which has cooled near the surface. Usually black, makes excellent road metal and gives rise to fertile soils.

Gabbro. Similar to dolerite but deeper seated. A dark and heavy rock often containing iron ores.

Basalt. A very common type of volcanic rock giving fertile soils. Dark in appearance and heavy. The crystals may be so fine that they cannot be seen by the eye alone.

Pegmatites. Coarse textured crystalline masses are usually collectively called pegmatites. They can hence be very varied in appearance.

METAMORPHIC ROCKS. When either the sedimentary or igneous rocks are subjected to great pressure and heat their characteristics may be so altered that an essentially different type of rock results. These altered rocks are placed in the category of metamorphic rocks. These rocks are very varied depending on the degree of metamorphism, but generally they are more compact and more resistant as a result of the alteration. We may distinguish four main types of greater importance to the geographer as follows:

Gneiss. Chiefly an aggregate of quartz, felspar, and mica, derived from either granite or near sedimentary rocks. These rocks are typical

of the older parts of the world. They are very resistant and give poor soils.

Schist. Somewhat similar to the gneisses but darker in colour and finer in grain. Originally basic igneous rocks or shales with a great amount of alteration. Gives soils a little more fertile and is perhaps less resistant than gneiss.

Slate. This is a metamorphosed clay or shale. The chief characteristic is a thin cleavage which cuts across the original bedding planes. It is valuable for building purposes. The soils derived from the rock vary according to the constituents.

Marble. This is a metamorphosed limestone. The original rock is much altered. All fossils disappear. As marble is derived from limestone it is less resistant to solution erosion than other metamorphic rocks. Some special types are valuable for ornamental building.

12 An Earth Sculpture Tank

Various attempts have been made during recent years both by geographers and engineers to study the processes of physical geography within the laboratory. The investigation of problems such as the behaviour of breaking waves on a foreshore, the formation of offshore bars, and the grading of rivers, etc., is highly complex research clearly outside the scope of any school practical work. But the type of apparatus which has been used for these investigations can be adapted very effectively to demonstrate many essential processes in the evolution of both inland and coastal features. Problems associated with the experimental technique such as the correct scale reduction and the accurate measurement of small quantities, together with disturbing factors such as capillarity and surface tension, which tend to mask or upset the gravity effect of running water, can all be ignored by the teacher who will only be concerned with simple examples of the way in which streams, rivers, and the sea produce and modify the physical landscape.

Whilst the university worker has his apparatus within the laboratory the teacher will probably find it necessary and desirable to build his earth sculpture tank in the open. For school demonstration purposes the tank need be nothing more than a watertight rectangular container about 6 ft. by 4 ft. in plan and 2 ft. in depth. If a permanent construction be envisaged a brick

base with brick walls and a covering of waterproof cement may be used, but if a less permanent fixture is desired a strong wooden container sheathed with lead or aluminium sheet metal will suffice. At least two outlet holes with removable plugs should be provided: one of these will drain the tank and to the other short sections of pipe may be fixed to provide a variable height overflow outlet when water is being run into the tank. A water supply should be laid on at one end, metal piping being used for a permanent fixture although rubber garden hose will suffice for simpler cases. Piping from the outlets to the nearest drainage channel must also be arranged.

At the end opposite to the water supply a wave agitator is inserted. This consists of a vertical sheet of wood or metal running the full width of the tank and hinged at the base. The wave agitator is moved to and fro by a geared handle (Meccano parts are very suitable) and this may be powered in turn, and usually very readily, by the class of pupils watching any demonstration.

In the end of the tank near the water supply a fine-sieved moist sand is introduced and a topography roughly and quickly moulded by hand. The landscape so created being of course appropriate to the process and features to be demonstrated. At the other end of the tank water is run in to a depth of say 6 in., and a sea and shoreline will then be created for the land mass that has been built up.

The essential ingredients have now been provided for the effective demonstration of the evolution of a multitude of physical features and the forces at work in their production. We may briefly indicate some aspects: others will occur to the teacher, the model for instance might be adapted to show the evolution of local features of interest.

RIVER EROSION. A stream bed is roughly prepared and water allowed to run down it into the sea. The movement of sand particles is clearly seen as the stream rapidly grades its course. An increase in the water supply will cause renewed erosion and if carefully controlled it should be possible to produce *river terraces*. The process of *meander migration* may be demonstrated by starting with an irregular stream course, and if this is very irregular cut-throughs and *ox-bow lakes* may develop.

RIVER CAPTURE. If two stream courses be marked out, one approximately at right angles to the other, and the water inlet of the shorter and lower stream be embedded in the sand, it will be possible to simulate *headward erosion* and *river capture* by gradually pulling back the pipe carrying the shorter stream's water supply. The sequence of events at the capture, the divergence

of drainage, and the drying up of the lower parts of the captured stream will be clearly and vividly demonstrated to a class.

DELTA FORMATION. If the stream be allowed to run into a sea the check in the velocity of the water and the resulting deposition of the load being carried will be quite obvious and soon a delta is in course of construction. Many of the grains will be deposited early to form the *topset beds* whilst others will rest on the face of the delta to form the *foreset beds*. The larger grains will be observed to roll down the face and spread farther afield to form the *bottomset* beds. The growth of the delta will be rapid and the foreset beds will be seen migrating across the bottomset beds.

REJUVENATION. This may be simulated by running a stream until the river bed is reasonably graded and then suddenly dropping the level of the water in the tank. The stream will now start to dissect its own delta and a *rejuvenation head* will be observed to travel upstream. This will probably flatten very quickly in the material being used but all the essential aspects of rejuvenation will be brought out. It will be noticed for example that the river in the rejuvenated section will, because of increased slope and hence velocity, carry much heavier loads than in the older, graded section.

EFFECT OF HARDER ROCKS. A layer of clay or Plasticine may be embodied in the course of a river to simulate the presence of harder rock strata in nature. The creation of a *waterfall* and its migration, the effect of a *local base level* control, and the varying results associated with different dips may be easily demonstrated.

COASTAL DENUDATION. If a shoreline be arranged and the wave agitator worked effectively, *cliffing* of the coast will normally ensue. If the original topography be suitably constructed, the infilling of bays and erosion of the headlands will normally follow, together with the formation of *stacks* and *islets*.

Cliffs will not normally develop to any great height because in the looser unconsolidated material needed for the stream experiments they will soon subside by *landslides*. This again, however, merely illustrates in a minor way the real process in nature, especially as these landslides will be observed to occur on curved slide planes (simulating the rotational shear slip).

COASTAL ACCRETION. If the shoreline be arranged at an angle to the oncoming waves and a stream is slowly introducing material at some favourable point, it may be possible to demonstrate the evolution of a *spit* with a backing lagoon.

If a very gentle gradient be arranged for the beach it may with long waves prove feasible to develop *offshore bars* and offshore rolls on the sea floor.

CHANGES OF SEA LEVEL. By having several overflow pipe outlets of varying length it will be possible to alter the sea level at will. Clearly this enables the effect of a rising and falling sea level to be demonstrated. The rise in sea level may, with a little foresight, adequately show the typical *drowned coastline* with its high degree of indentation and submerged valleys.

A fall in water level will demonstrate the abandonment of an old sea cliff, the emergence of a raised, wave-cut platform, and the subsequent production of a further cliff line at a lower level.

These visual demonstrations suitably backed by a running commentary can be of great value to a young audience faced for the first time with concepts probably completely new and quite strange. In real life most of the processes take place so slowly or on such a large scale that they cannot readily be comprehended 'in the field'. The earth sculpture tank however, by scaling down the size and accelerating the time factor, permits a quick appreciation of the fundamentals in the fascinating story of the evolution of inland and coastal topography.

Whilst controlled experiments within the school grounds are perhaps the most desirable a second substitute may be possible in some districts should the enthusiastic teacher find himself blocked by lack of space or materials. In coastal localities small streams frequently flow over sandy beaches and through rocky pools at low tide: these can rapidly be modified or adapted to illustrate any of the processes noted above. Inland small streams on sandy incoherent beds are less common but may in favourable circumstances exist: attention can be drawn to these on field walks.

Clearly however the school earth sculpture tank is to be desired and in its simplest form need involve very little outlay. Many improvements can of course be made and the interested teacher may desire to develop the idea further. Some suggestions are therefore appended for refinements and care and maintenance:

(*a*) The wave agitator may be driven by a small electric motor which can be clipped to the side of the tank and plugged into the nearest supply point.

(*b*) Imitation rain may be made by the use of a paint spray and foot pump —or the spray may be driven by an electric motor. Some vacuum cleaners have attachments that can be adapted for this purpose.

(c) If a long running experiment proves possible then the gradual evolution

of a topography from an initial series of hard and soft rocks may be demonstrated. Alternate layers of sand and clayey sand will simulate these conditions. The initial topography can also be 'folded' or 'faulted' to demonstrate the effects of structure.

(*d*) A wooden cover should be made for an outside earth sculpture tank to keep the sand clean and exclude rain.

(*e*) The tank should be emptied after use and the sand allowed to dry. Algae will otherwise develop on the sand grains. The addition of a small amount of lime or carbolic to the water will reduce this tendency if a long experiment is envisaged.

13 Models of Land Form Features

The difficulty often experienced by younger audiences in appreciating the full significance of land forms may to a large extent be overcome by a combination of photographs and models. Whilst time will certainly not permit the construction of more than perhaps one model per pupil, a very effective and helpful range of models can be produced by a class if each pupil is given a different task. The better results can then be kept for future use and in a short space of time a representative collection will be built up in which the common physiographic forms are illustrated.

It is suggested that models of this type should be 'hand specimens' measuring no more than some 3 or 4 in. on the base and perhaps an inch or two in height. Each model should aim at showing one or two main morphological features only, and these should be simplified in order to bring out the essential parts. Mediums for the construction of the models are numerous and the choice will to some extent depend on the age and capabilities of the class: papier mâché, Plasticine, modelling clay, and plaster work are all possible. For permanent retention it will be advisable to take a plaster cast and mount the finished model on a wooden base. The skilful application of appropriate coloured paint will, of course, much improve the result.

In explaining to the class how to build up or carve out the various features it will probably be helpful to relate the land features to simple geometrical forms with which the class is familiar. It is rather interesting and fortunate that nearly all land forms can be visualized as parts of, additions to, or subtractions from a group of simple geometric shapes (e.g. fig. 28 (*b*)). We may distinguish:

(*a*) The prismatic block; this will, in the upright case, form the basis for modelling escarpments (fig. 28 (*a*)), terraces, ridges, mesas, sea cliffs, etc. If inverted, asymmetrical valleys, canyons, etc., result.

(*b*) Pyramids are useful analogues for certain types of mountains and buttes.

(*c*) Cylinders may be used as a base for simple folded strata. The section can be made oval instead of circular for steep folds. Inverted, the cylinder shape forms the basis of wide valleys, glacial troughs, etc.

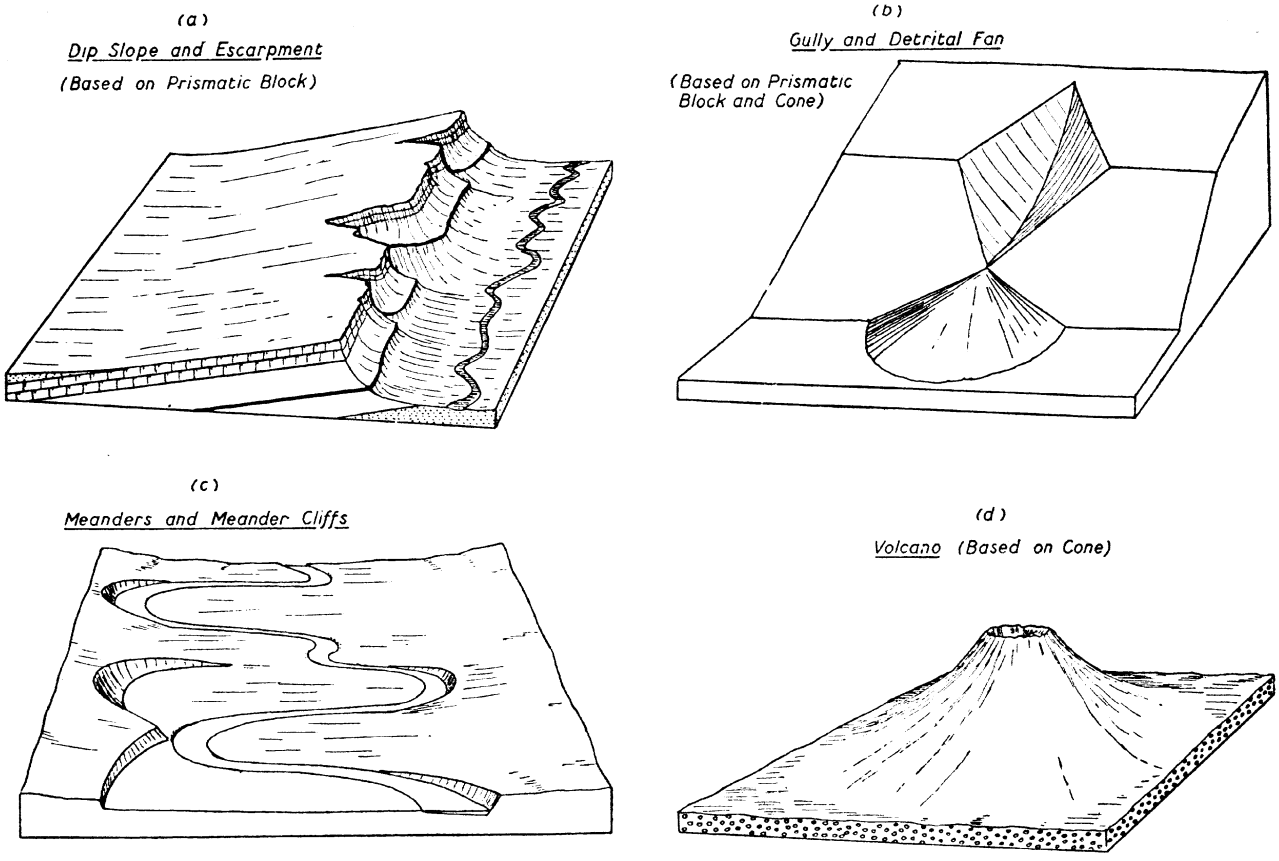


Fig. 28.—Models of land form features.

(*d*) Hemispheres make a useful base for acid lava mountains, dome-shaped folds, and some types of drumlins.

(*e*) Cones may in the normal case make useful analogues for volcanoes (fig. 28 (*d*)), some types of mountains, detrital fans, etc. In the inverted case craters and corries will be simulated.

Some of these commoner physiographic forms that can be effectively treated in this fashion may be briefly summarized as follows:

LAND FORMS OF THE NORMAL SUB-AERIAL CYCLE. Youthful valleys, gorges, waterfalls, interlocking spurs. Mature valleys, meanders, oxbow lakes, braided channels. Escarpments and dip slopes, hogbacks, cuestas, water and wind gaps. Effects of rejuvenation, river terraces, incised meanders. Headward erosion, river capture. Mountains in a youthful stage of dissection, mountains in a mature stage of dissection.

LAND FORMS OF THE ARID CYCLE OF EROSION. Dunes, barchans, longitudinal dunes, alluvial fans and cones. Badlands, inselberg, zeugen, mesas, buttes. Pediments.

LAND FORMS ASSOCIATED WITH GLACIATION. Glaciers, terminal, lateral, and medial moraines. Pyramidal peaks, nunataks, arêtes, hanging valleys. Fiords and glacial troughs. Proglacial lakes, deltaic deposits, scree fans. Drumlins, eskers, osar, kames. Glacial lake country. Kettle and knob topography.

COASTAL LAND FORMS. Deltas, estuaries, submerged valleys. Cliffed coasts, arches, caves, islets, stacks. Beach ridges, spits, bars, offshore bars, cuspate forelands. Shorelines of emergence, shorelines of submergence.

VOLCANIC FORMS. Volcanoes, craters, lava flows. Lava domes. Volcanic necks and plugs. Dykes and sills.

Whilst simple hand specimens have been suggested as aids to a fuller appreciation of the morphological features, it will be apparent that more complicated models can be attempted incorporating several features; for example, a piece of glaciated country, various stages in the evolution of the normal geographical cycle, or a more extensive stretch of coast. These might be attempted by more advanced classes and in periods when ample time is available—the interval between a public examination and the receipt of the result might thus be utilized.

14 Models to illustrate simple Geological Concepts

Even at school level a proper appreciation of many geographical relationships sooner or later involves an understanding of certain geological structures. Since this involves three dimensions it is not always easy to explain to a large class with the aid of a blackboard alone—even when the teacher is quite good at three-dimensional drawings. Small 'hand specimen' models similar to those suggested for illustrating morphological features, i.e. about 3 in. by 4 in. by 2 in. in size will often be found to be helpful in explaining simple geological terms, and also in showing the relationship between the underlying geology and the morphology.

The models may be either temporary 'evolutionary' models or more permanent static models. For the first category it is preferable to use a malleable material and coloured modelling clay or Plasticine is probably the best medium. With this method various layers of coloured clay are built up into a solid block which can then be used for a wide variety of demonstrations, as, for example:

(*a*) The block is laid flat on the bench and a valley with a normal profile is cut out: this will demonstrate the relationship between the outcrops and the contours for a simple case.

(*b*) The block is tipped slightly and the top cut off with a sharp knife. This may be used to demonstrate the relationship between the width of the outcrop and the dip of the beds. A valley may now be carved out and the run of the geological boundaries relative to the relief will be immediately apparent (fig. 29 (*b*)).

(*c*) The block is placed between two parallel boards which are slowly pushed together. This will simulate the effect of folding (fig. 30 (*b*)). If one board is held fast and the second moved, it may be possible with a little encouragement to produce overfolding. In either case the top material may then be sliced off and the nature of the outcrops in a denuded fold will be at once apparent (fig. 30 (*c*)). Minor valleys may then be cut to show further variations.

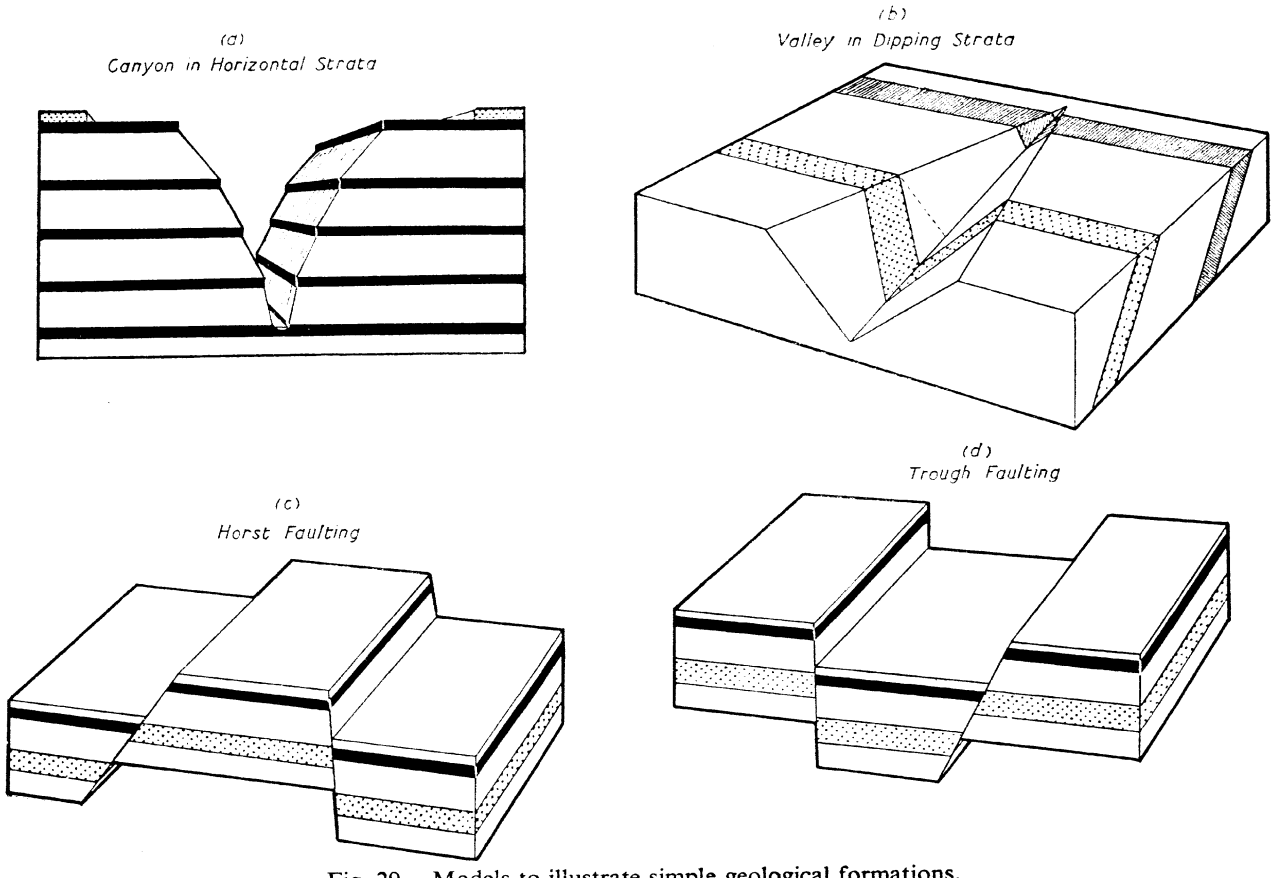


Fig. 29.—Models to illustrate simple geological formations.

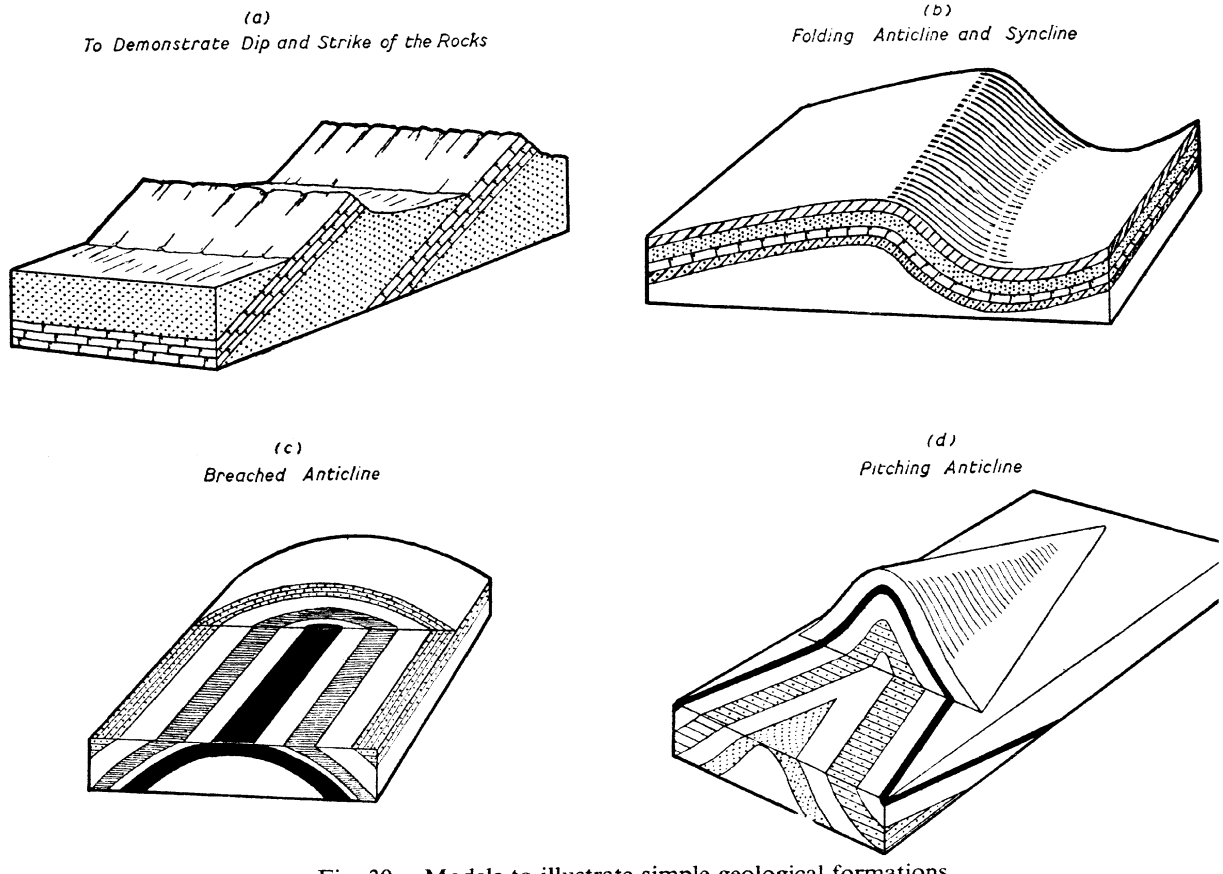


Fig. 30.—Models to illustrate simple geological formations.

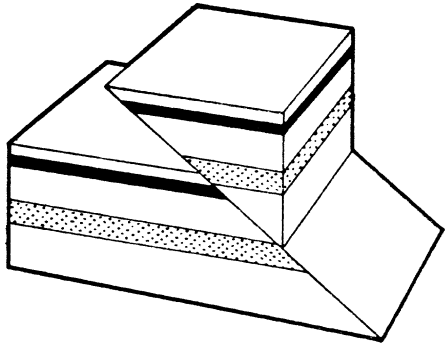
(*d*) The block is tilted slightly and the top again cut off to produce a plain of differing outcrops. A cut across the strata is then made to simulate a fault. The two parts may then be moved in at least four different directions (relatively) to show the varying effects which arise according to the lateral or vertical displacement. It will soon be appreciated that there is a limitless number of end-results according to whether the cut (the fault) is vertical, at an angle to the vertical, in the direction of the dip or strike, or oblique to both, and whether there is lateral and/or vertical displacement. Some examples are given in the sketches (fig. 3 (*a*), (*b*), (*c*)). The numerous types need not concern the geographer unduly, but they are, of course, vital and of great importance to the structural geologist.

If desired, valleys may be cut out after the faulting has taken place, to study further the relationship between the run of the geological boundaries and the morphology when the complication of faulting is added.

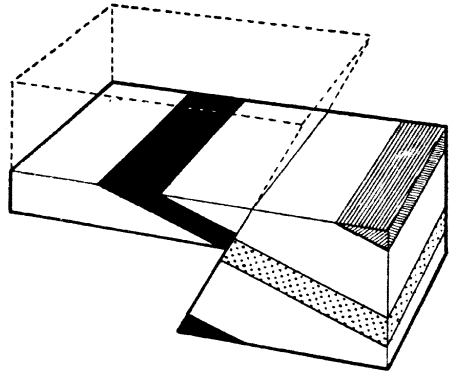
In the second method more permanent models can be made, either as static models which may be constructed in wood or plaster, or as 'animated' models probably best made in wood. In the static model the strata may be painted on the side of a simple plaster cast, and any of the relationships discussed in sections (*a*) to (*d*) above may be illustrated. It may not be apparent to the class, however, exactly how the end-result is arrived at with the static model. Hence an alternative is to arrange for 'animated' models which are best constructed from different layers of wood suitably coloured and then stuck together.

Thus, in the case of (*a*) above, the valley can be sawn out after the block has been assembled, and the piece removed should be kept with the original block. Similarly, in (*b*) the top piece sliced off should be kept with the pieces cut out to represent the valleys. The steps by which the end-result is achieved can then be demonstrated to the class. A representation of the folding is admittedly more difficult with wooden strata, but the method is admirable for faulting where the whole process of movement and subsequent dissection can be demonstrated with ease.

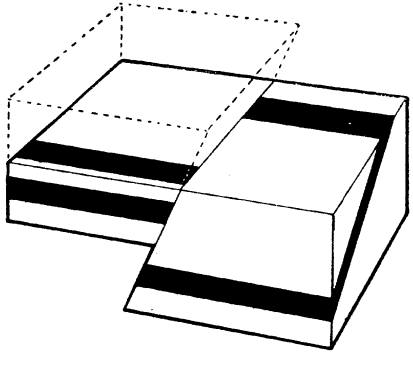
Either method is clearly capable of extension into more complicated cases —unconformities, nappe structures, etc., can, for example, be similarly demonstrated.



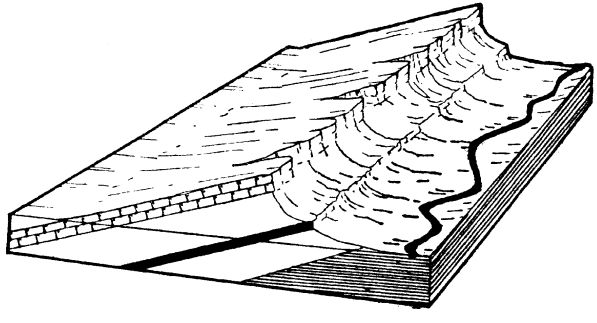
(a) Thrust Fault



(b) Reversed Strike Fault: Cutting out of Beds



(c) Reversed Dip Fault: Shifting of Outcrops



(d) Simple Dip and Strike

Fig. 31.—Models to illustrate simple geological formations.

15 General Relief Modelling

(a) Contours for Beginners

A map is an instrument designed to show accurately space relations in a horizontal plane. As a result the most difficult subject for cartographic illustration is relief, since its measurements are vertical. The most accurate, indeed the only generally satisfactory, method is by means of contours or lines of equal height. The interpretation of elaborate contour maps needs care and close attention even by the expert, and it is to be expected that younger pupils will find some difficulty in understanding even elementary contour maps.

The simple method illustrated in fig. 32 is designed to give a clear start in the work of interpreting contoured maps. A simple relief form is constructed from clay at the bottom of a trough. The trough should preferably be made of glass, although a pneumatic trough from the chemistry laboratory will serve quite well. In the case figured, an island with two peaks separated by a col has been built. Water is poured into the trough to a depth of 1 in. and the shoreline of the reduced island is scratched on the clay by a sharp-pointed instrument. Pupils readily appreciate that every point on this line is 1 in. higher than the original coastline. The process is repeated inch by inch as water is added, until the island is completely submerged: the tank is now emptied.

On looking down on the island at this stage the view illustrated below the elevation will be obtained. This contour map of the island with a vertical interval of 1 in. should now be copied by the class. Spot heights such as the peak and the top of the col may be determined from the depth of water needed to submerge them and then added to the map.

The contours for many different types of land forms—peaks, cols, valleys, ridges, etc.—may be obtained by this method and a knowledge of slopes, gradients, etc., deduced by the pupils. This type of model is also of value when teaching section drawing, for the pupils can construct a section along a given line across the contour map and then compare their result with a knife-cut section taken through the clay model.

For a more permanent exhibit the bottom of the trough should be covered with cardboard or tin and the model, when dry, lifted out. A series of models, each accompanied by a contour map drawn by the pupils, and illustrating well-marked land forms, will greatly accelerate a full appreciation of contours if left on display for some time.

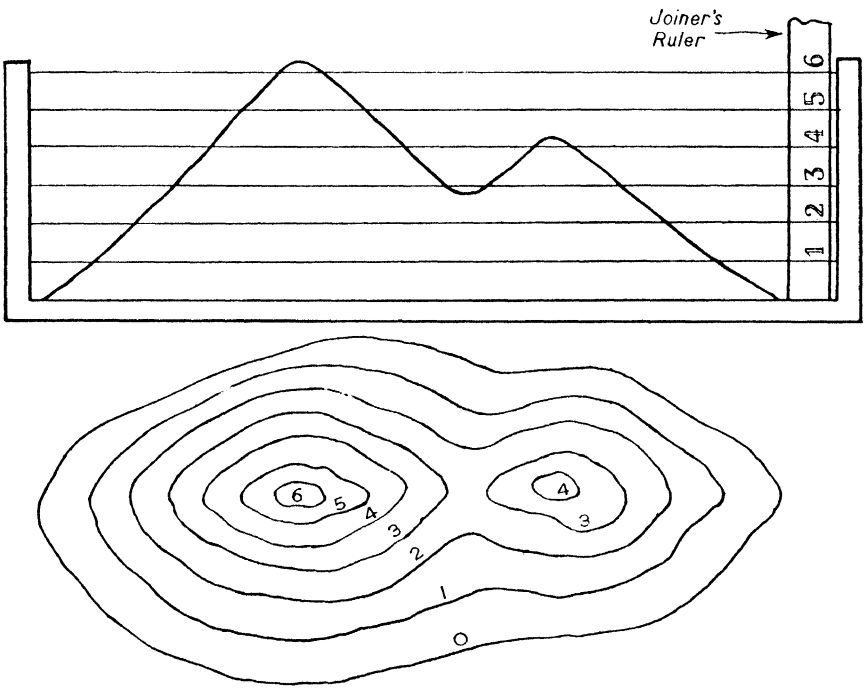


Fig. 32.—Contours for beginners: the tank model.

(b) The Layer Method

Children can learn a great deal about contour maps by constructing relief models from them. In general the idea reverses the procedure in (*a*) above, but the relief modelling should only be attempted when some experience in reading contoured maps has been gained. There are various methods of modelling an area of country of which the most accurate is probably the layer method.

Though somewhat tedious where the land is intricately sculptured, this method should be the first attempted in school, as it not only aids in the interpretation of contour forms, but is admirably suited to corporate effort. A region of moderate relief, preferably known to the pupils, should be chosen. The 2½-in. O.S. map will often prove a suitable scale and base on which to work. A tracing of the contours is made and copies of this are duplicated for distribution to the pupils, together with pieces of cardboard of adequate size and reasonable thickness.

Each pupil is allocated a different contour for his portion and shades the area of the map from that height upwards. The shape of the shaded area and the next higher contour are to be transferred to the cardboard and the area cut out as a pattern. The fixing of each succeeding layer in position is rendered easy by the drawing of the next higher contour on each piece. The assembled model will resemble fig. 33. In order to construct a fair-sized model, lesson-time in school may be saved by setting the pupils to do the actual cutting out at home.

After use in contour study, the terraces may be filled up with plaster of Paris or a suitable substitute. Further interest is added if the relief model can be taken out into the field and compared with the actual relief.

A large class would enable perhaps two complete models to be assembled, and one of these can with advantage be left in the terrace form. Detail may be added to the completed model, roads, railways, and rivers being easily drawn on. A colour may be used for towns, woodland, orchards, etc. For large scales it may be possible to add a note of realism by placing small coloured blocks in position for houses, farms, etc., whilst a three-dimensional

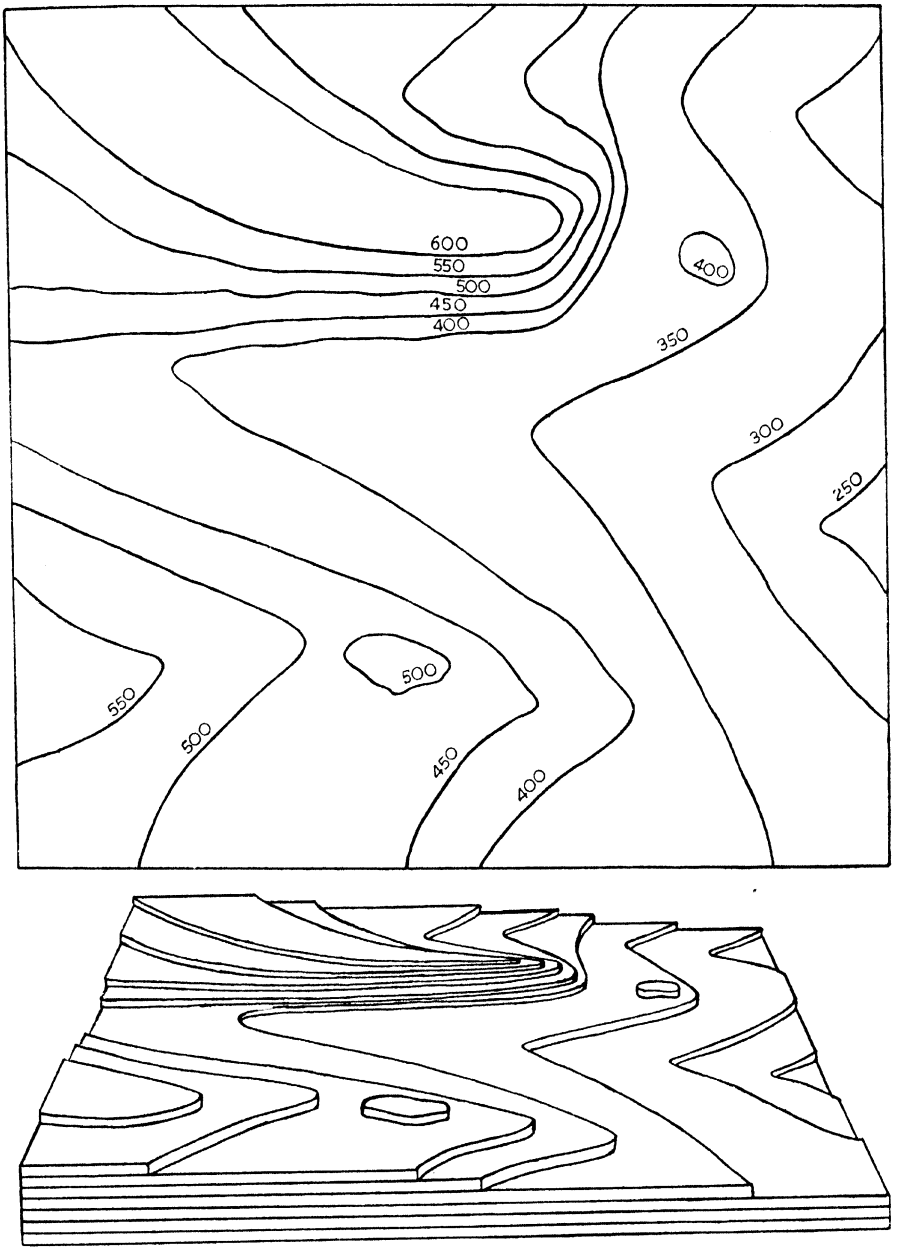


Fig. 33.—The layer method of relief modelling.

effect for woods can be obtained by sprinkling green-dyed sawdust on a gummed surface.

A variety of substances may be used for the surface finishing. Plasticine, cement, and even flour dough may be employed, but the best is probably plaster of Paris: it should be noted that with the latter the mixing should be done in small quantities owing to its quick-setting properties. The latter is a distinct advantage for the cardboard will not swell: the final surface also takes a coat of paint well and after painting is less liable to break.

(c) The Section Method

Though easier to make in the case of intricately sculptured areas, this is not so accurate as the layer method. Even close parallel sections will be found to differ a great deal. Sections are drawn on parallel lines on the map, and these should lie across the grain of the land. Thus, in the case of a relief model of northern England, the sections would be drawn from E.–W., whereas in south-east England the sections would run N.–S. The vertical scale should be adapted to the degree of relief of the area, but moderated in the interests of natural appearance in the finished model. An interval of $\frac{1}{2}$ in. is suitable for a small model on a horizontal scale of $2\frac{1}{2}$ in. to 1 mile for most parts of lowland Britain.

The sections are drawn on thin cardboard, cut out and erected along lines

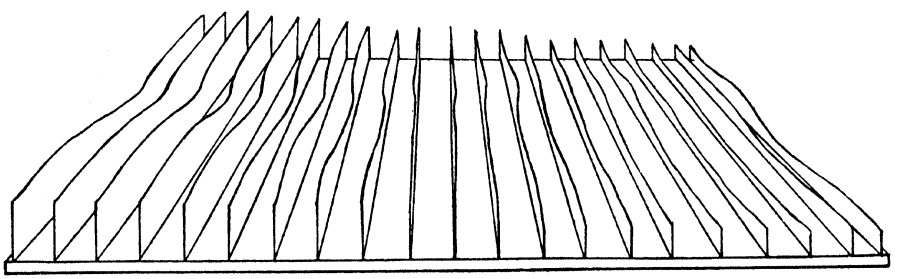


Fig. 34.—The section method of relief modelling.

drawn appropriately on a replica of the map. If the latter be on a baseboard the sections can be held in position by pins fixed edgewise. The pins can subsequently be removed. The spaces between the sections are then filled with plaster of Paris, paying close attention to the original map during the process. The model is then painted and finished off as in (*b*) above. An example is shown in fig. 34, where sections which would have been used for the same topography as that employed for the layer method have been assembled.

(d) The Peg Method

This is really a cross between (*b*) and (*c*), but is less accurate than either. Pegs cut to the various heights of the contour interval are erected at suitable points on a replica of the map. All those on a contour being, of course, of equal height. Others cut to the correct length are added at spot heights and the model built up to the heights of the pegs with plaster of Paris.[1]

(e) The Paper Strip Method

A modification of the peg method involves the use of narrow strips of thin cardboard whose widths correspond to the heights of the contours. These strips are bent to lie along the contours and fixed by pins, as in the case of the sections. A model of terrace formation similar to the unfinished layer model may be made first by plaster filling or the relief model completed, as in the case of the section method. The pins are afterwards withdrawn in either case.

[1] A cast may be made of any of the foregoing models and copies made from it. Where the original filling was plaster, however, the surface should be painted with a hard gloss paint and allowed to dry thoroughly. Models may also be constructed on thin sheets of glass placed above the base map. The glass may be removed from the finished model when it is set. The use of the glass obviates the task of copying the map: this may on occasions be advantageous.

SECTION C

THE ATMOSPHERE AND THE OCEANS

16 The Construction of Meteorological Instruments

(a) A Simple Cup Anemometer

THE model illustrated in fig. 35 is, except for the cups and stand, composed entirely of Meccano parts. The four cups may be constructed from cardboard or very thin tinplate, and are conical in shape. Each cup consists of a sector of a circle 8½ in. in diameter with an angle of 210°, which gives a cone with an aperture of approximately 5 in. The cups are fixed to an angle bracket bent to the required shape. If cardboard is used it will be necessary to wax or oil the surface for exposure in rain.

Liberal oiling of the working parts is essential to ensure that the instrument will turn in gentle winds, and it may be desirable to grind the lower end of the vertical axle rod to a point and rest this on a sheet of glass fixed to the top of the wooden post under the flanged plate.

With the gearing illustrated, the tin pointer, on the reverse side of that shown in the main elevation and indicated in the inset, will revolve slowly at one-fiftieth the rate of the anemometer cups. The number of revolutions in a given period of time may thus be counted. By comparison with a standard instrument or by comparison with the Beaufort scale of wind force, the anemometer can be made a useful adjunct to a school meteorological station.

The Meccano parts employed in the construction are as follows: No. 1—2; No. 5—2; No. 12—4; No. 15*a*—1; No. 16—1; No. 22—1; No. 24—2; No. 28—1; No. 32—1; No. 37*a*—22; No. 37*b*—22; No. 52—2; No. 54—2.

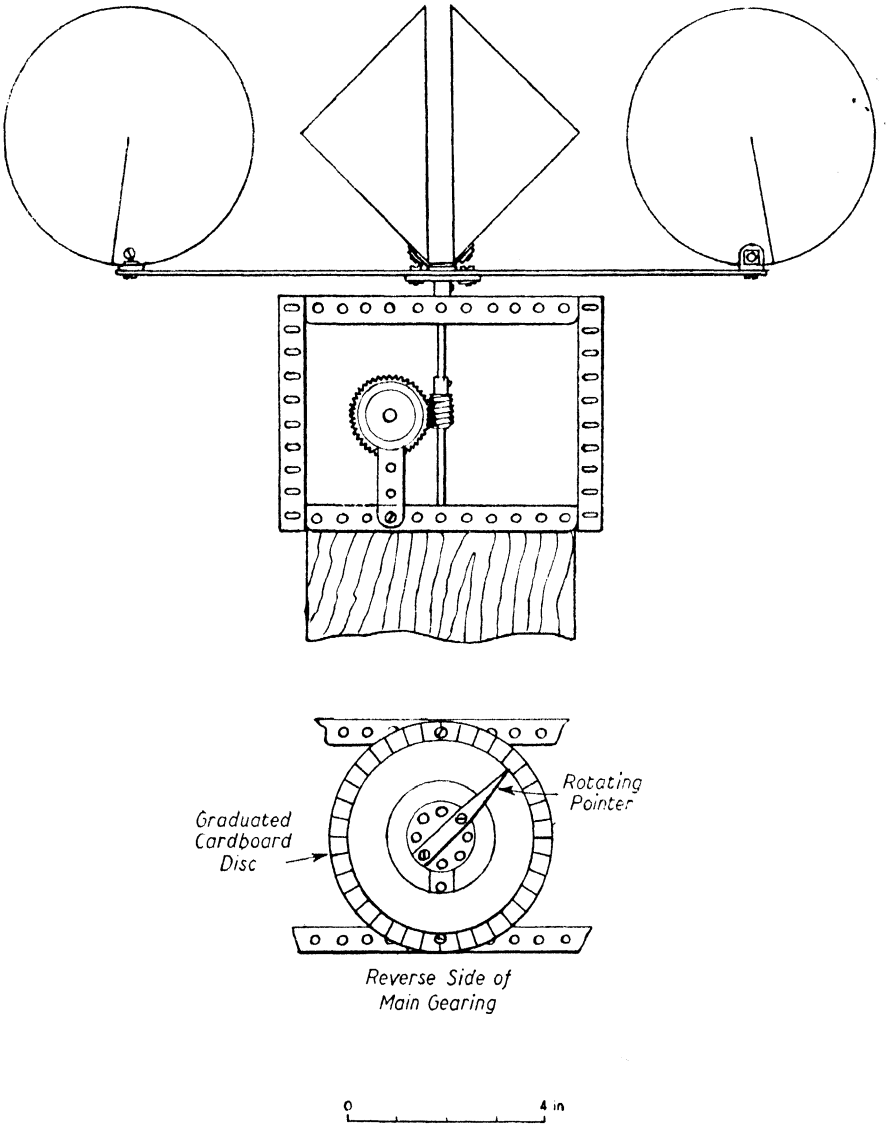


Fig. 35.—A simple cup anemometer.

(b) A Combined Wind Vane and Anemometer

Schools possessing facilities for metal work would find no difficulty in constructing the large vane shown in fig. 36. The vane is entirely built of metal, sheet-iron being used and treated to prevent rust. The split wings should make an angle of about 22° with each other to ensure maximum stability. For easy turning, the front hub of a bicycle has been incorporated, the vane being riveted through several of the spoke-holes. Old hubs are cheaply obtained from cycle-repair shops and, if necessary, new ball-races can be added. The point of the arrow should be weighted and possibly lengthened in order to balance the wings.

The anemometer is of the pendulum type and consists of sheet-iron. According to Haynes,[1] with material weighing 14 oz. per sq. ft., the arc may be graduated for the Beaufort scale as follows:

Force	2	3	4	5	6	7	8
Angle of plane to vertical	4°	15°	31°	46°	58°	72°	81°

It will, however, probably be found necessary to graduate the anemometer, when made, by direct comparison.

Where metal work does not form part of the curriculum a similar vane may be constructed from wood. An example, shown in fig. 37 (*a*), is largely made from plywood. The pendulum (fig. 37 (*b*)) could be fixed to the vane between the hub and the point in order to balance the wings. Note that if the above scale is employed sheet lead should be attached to the back of the pendulum plate to give the necessary 14 oz. per sq. ft.

Many alternative constructions will occur to the mechanically minded, and Meccano parts will be found very suitable, especially for fixing the pendulum to the vane in the wooden model.

[1] *Techniques of Observing the Weather*, Haynes, Wiley & Sons, New York, 1947.

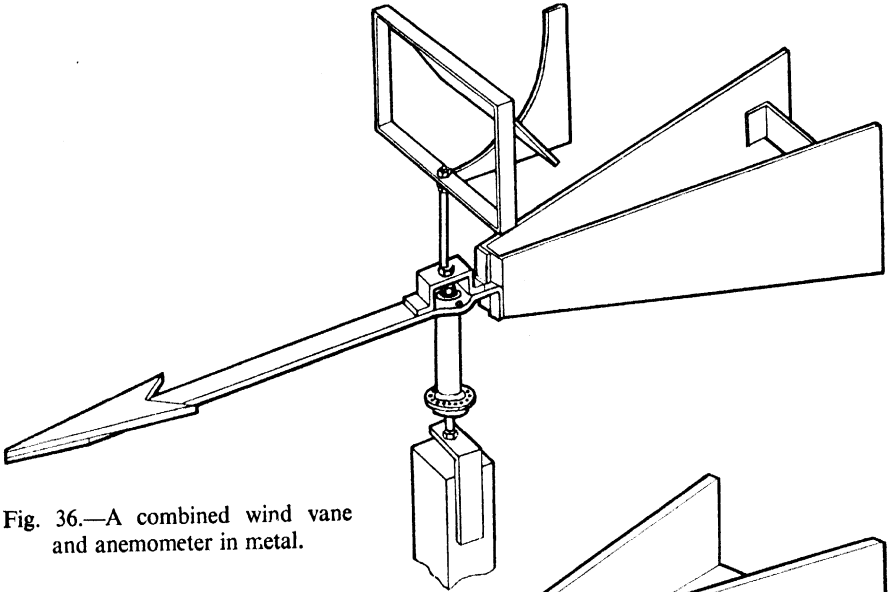


Fig. 36.—A combined wind vane and anemometer in metal.

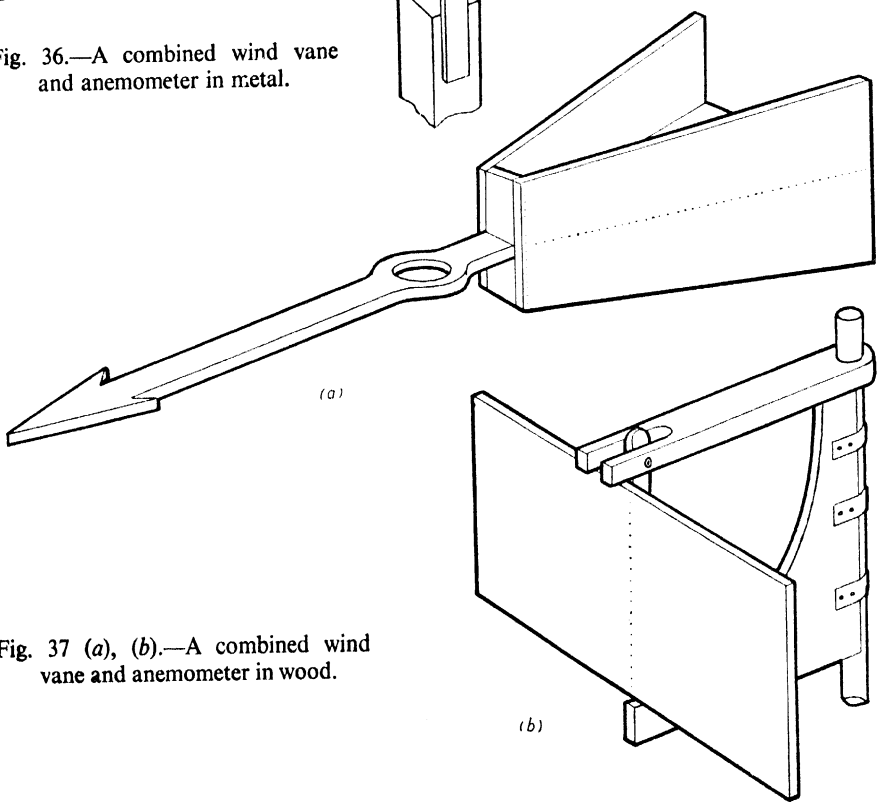


Fig. 37 (*a*), (*b*).—A combined wind vane and anemometer in wood.

(c) The Measurement of Rainfall

It is unlikely that a school will be unable to obtain a rain gauge, but not infrequently a pupil will show great keenness and wish to make his own meteorological observations at home. It will therefore be of assistance if the master can suggest a suitable method for the construction of a gauge. A serviceable model may be constructed on the lines illustrated in fig. 38. The outer casing is a 4-in. sewer pipe. This should be stood upright on a board and a rich sand-concrete mixture in a semi-fluid condition poured in and left to set: this will form a bottom. An ordinary tin-plate funnel or, as an alternative, a glass funnel is used to collect the rain. A good size would have a diameter of 5 in.

The measuring cylinder consists of a length of glass tubing closed by a well-waxed cork at the lower end and of internal diameter 1 in. The tube should reach nearly to the cone of the funnel, and, as 1 in. of rain in the funnel would require a considerable amount of measuring tube to contain it, the latter should be stood in a tin receptacle to collect any overflow. This can then be measured and added to the total in the tube.

It would be an advantage to drill a hole just above the top graduation to ensure overflow at that amount. The graduations on the tube are shown by means of a strip of paper fixed to the tube. The lower end should coincide with the upper surface of the cork and should be covered with a thin layer of molten wax.

If carefully constructed and graduated, this type of instrument can give quite good results; but the order of accuracy would not, of course, be acceptable for any official recordings.

(d) Changes of Pressure

A pupil who does not possess a barometer may observe changes in atmospheric pressure by means of a simple variometer (fig. 39). This is essentially a closed vessel connected to a capillary tube in which there is a short column of mercury or oil. A Thermos flask should be used for the 'closed vessel' and the flask should be enclosed in a box of hay or cotton-wool, otherwise there

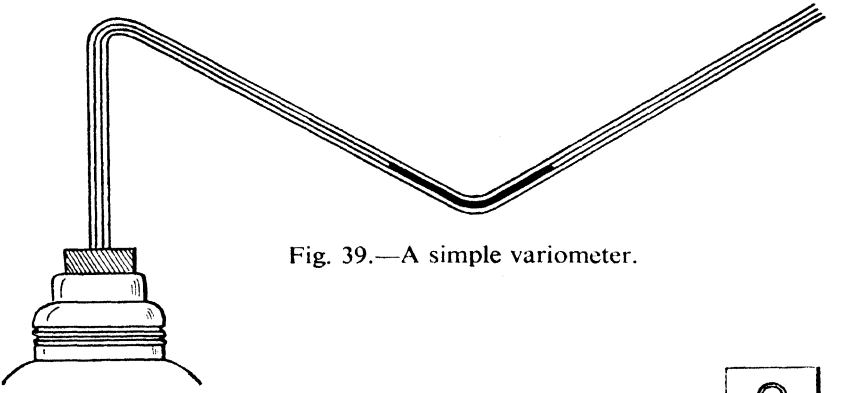


Fig. 39.—A simple variometer.

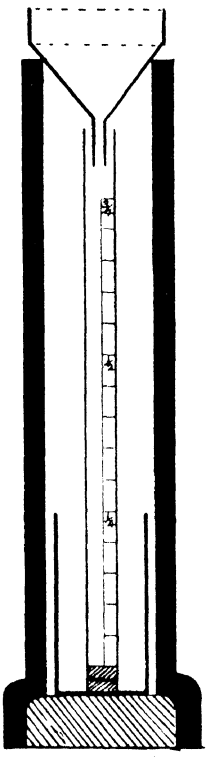


Fig. 38.—A rain gauge.

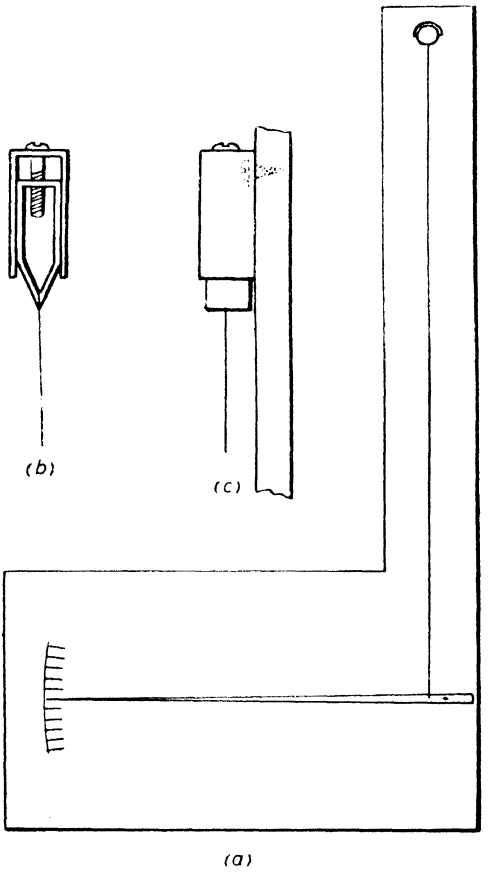


Fig. 40.—A simple hair hygrometer.

is a danger that temperature changes will far outweigh pressure changes, and the instrument will then merely become a crude thermometer. The bung and the tube must also fit tightly and should be sealed with wax or some similar airtight substance.

If the vessel has a capacity of half a litre and the tube a sectional area of 1 sq. mm. a fall of pressure involving an expansion of the air in the vessel by, say, a quarter of a c.c., would mean that the thread of mercury would move outwards by some 25 cm. A very long tube would therefore be needed, or a much wider bore. No liquid is an effective seal unless the bore be narrow, but this disadvantage may be offset by bending the capillary into a V- or U-shape, and this will permit a wider bore tube to be safely employed.

(e) Changes of Relative Humidity

The relative humidity is best obtained by means of a wet and dry bulb hygrometer, but if the necessary thermometers are not available a hair hygrometer may be employed. At its best this is by no means a precision instrument, and as it is difficult to ensure that each member of a bunch of hairs is taut the home-made instrument should be very simple and preferably consist of a single hair.

The hair employed in the instrument shown in fig. 40 (*a*) has an actual length of 15 in. Short hairs are not effective and, as it should be human hair, the production of this part of the apparatus will in these days cause a certain amount of interest. The pointer consists of a pared strip of bamboo and has sufficient weight itself to keep the hair taut. The hair is soaked for a day in a grease solvent (benzine, Thawpit, etc.), and is then gummed at one end to a large draughtsman's drawing-pin in such manner that the turning of the pin will wind up the hair. The other end of the hair is tied to the pointer immediately in front of the pivot, which consists of an entomological pin passing through a carefully made hole in the bamboo. A scale is then drawn on the supporting board. This can be graduated by comparison with some other form of hygrometer or by the following method.

A closed container large enough for the instrument is obtained and a

solution of sulphuric acid of strength 70 per cent is introduced into the container. Within a short space of time the relative humidity in the container quickly drops to 4 per cent; this point on the scale may be marked. Wet cloths are next introduced into the container and the whole wrapped round with saturated towels. Within half an hour the relative humidity will be 100 per cent inside the box. This point also can be marked. Once these two points have been found the scale may be graduated according to the following table:

Relative Humidity	Change of length of Hair (% of total change)
0	0
10	20·9
20	38·8
30	52·8
40	63·7
50	72·8
60	79·2
70	85·2
80	90·5
90	95·4
100	100

This is clearly a very delicate instrument. A more robust type may be made using a group of, say, five hairs. The drawing-pin suspension is then, however, unsuitable and a simple suspension made from sheet-metal is shown in figs. 40 (*b*) and 40 (*c*). It should be noted that in this case weight must be added to the bamboo indicator and two or three wire paper-clips will be found suitable for this purpose.

17 A Simple Model of a Depression

Some pupils may find it difficult to understand the circulation of air in a depression, for neither a flat diagram nor a vertical section can illustrate it accurately. Though it cannot be claimed that the model illustrated in fig. 41 overcomes all difficulty, especially at the cold front, it undoubtedly helps those who cannot visualize the three-dimensional nature of the system.

As depressions vary so greatly in size, shape, and the regularity or otherwise of the isobars and fronts, it is desirable to simplify as much as possible. The fronts, although rarely regular, are best shown as slight curves. For the base of the model cardboard of moderate thickness is selected, and in the case of a young depression, marked as shown in fig. 41 (*a*). The cold sector should be coloured light blue and the winds shown in black, pink being chosen for the warm sector with the winds in red. A cut is made along the cold front from the centre to the point *Z*, and along the warm front from *X* to *Y*. The warm front is cut in thin cardboard to the pattern (*b*), coloured pink with pale blue on the reverse side, and the winds marked in red. As this front is designed to lean forward, the tab which is to be passed through *XY* is notched as shown. The cold front is cut to the pattern (*c*), coloured blue with pink on the reverse side: as it is designed to lean backwards the tab is merely clipped as shown. The tab at the edge of (*b*) is eventually gummed to (*c*) after assembly. The completed model is shown in (*d*); the acute angle between the warm front and the base should preferably be less than that implied by the sketch.

For an occluded depression the base is marked and cut as shown in (*e*). If a warm occlusion is intended, the lower portion may be represented by cutting to the pattern (*b*), but terminating at the dotted line; similarly, with pattern (*c*) for a cold occlusion. If desired, the warm sector that has been lifted off the ground can also be added.

Fronts drawn on the base should be given the appropriate symbols.

Fig. 41.—A simple model of a depression.

18 A Model Wind Rose

The model shown in fig. 42 was described by V. C. Spary in *The Geographical Teacher*, Vol. XI, Part 3. The young pupil's enthusiasm for the collection and graphing of weather records is apt to wane as the result grows more unsightly with continued handling and the correction of occasional errors, and the model is an attempt by Spary to overcome this deficiency.

Observations of wind direction and wind force at a standard time are made each day. It is fairly easy to determine wind strengths on the Beaufort scale by means of their mechanical effects, and this scale can, under supervision, be adopted for the present purpose. The general weather may also be classified as fine, rainy, or indefinite.

Thin strips of wood or cardboard are cut to length each day to represent the strength of the wind, and coloured red for a fine day, black for a rainy day, and left uncoloured for an indefinite day. The strips are placed in grooves cut in a wooden base in the appropriate wind directions.

In addition to serving as a wind rose, the model will also connect wind direction and force with the type of weather experienced. It is clear that other climatic elements can similarly be treated in order to retain the younger pupils' interest.

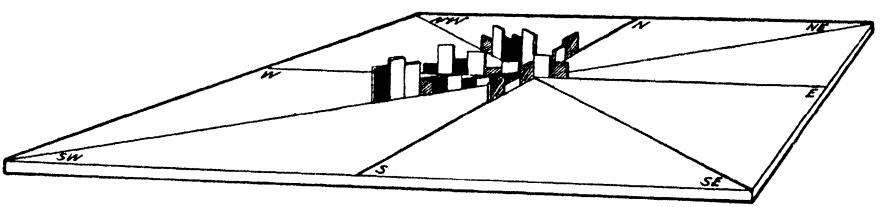


Fig. 42.—A model wind rose and weather record.

19 A Demonstration of Cold Air Drainage and Katabatic Winds

On calm and clear nights prolonged radiation causes a reduction of the surface temperature and, in consequence, that of the air in contact with the ground. In regions of diversified relief this has some interesting meteorological effects with important geographical implications. Exposed plateau surfaces are particularly prone to this form of temperature reduction, which is accompanied by an increase in the density of the air, with the result that the colder, heavier air tends to flow to lower levels. Valleys in close juxtaposition consequently tend to become filled during the night with cold and dense air. If the valley opens out in its lower reaches the cold air may be distributed as a shallow layer over a large area, but if the valley has any form of constriction, then ponding may occur, and the cold air will accumulate to considerable depths above the point of the constriction. The movement of the cold air down the slopes is known as a katabatic wind: it is quite noticeable and may be easily felt, although only occurring near the ground surface.

The reduction in air temperature will, of course, increase the relative humidity, and if the reduction passes below the dew-point of the air present, condensation occurs and a fog or mist results. This is more likely to occur in valley situations where the cold air has been ponded and continues to fall in temperature. Owing to the inversion of the vertical lapse rate which accompanies this process, these visible effects are usually referred to as inversion fogs. These fogs are likely to be common during winter in any low-lying situation which is surrounded by adequate cooling grounds.

A very neat demonstration of this process, which will readily fix it in the mind of any class, may be given with the aid of a model and a small supply of solid carbon dioxide. A simple model may be constructed with the aid of two sheets of glass, rectangular in shape, which are erected vertically about 3–4 in. apart on a wooden stand. A typical valley section is then constructed in the glass trough to one side with a flatter 'plateau' surface to the other side. This may either be built up with papier mâché, plaster, or run up quickly with the aid of some pieces of cardboard (fig. 43).

Solid carbon dioxide is the medium now widely used for ice-cream refrigeration and a small quantity for the experiment should not be difficult to obtain. Storage in a standard refrigerator will probably be desirable. Shortly before the experiment, lumps of the CO_2 are placed in the bottom of a tall canister which contains a small quantity of cold water. An artificial fog will rapidly appear and remain within the canister where the air is colder and denser than outside. This air may now be gently 'poured' on to the plateau of the model to simulate the conditions which arise on cool, calm nights of excessive radiation. It will be quickly observed how the cold and denser air flows down the steepest slope to accumulate in the valley, and with the continued addition of fresh supplies of cooled air, how the depth of the valley (or inversion) fog gradually increases.

The effectiveness of the demonstration can, of course, be increased by the use of more elaborate models and by a more precise control of the supply of cold air, but even the simplest assembly will serve to show the process of cold air drainage, katabatic winds, and inversion valley fogs.

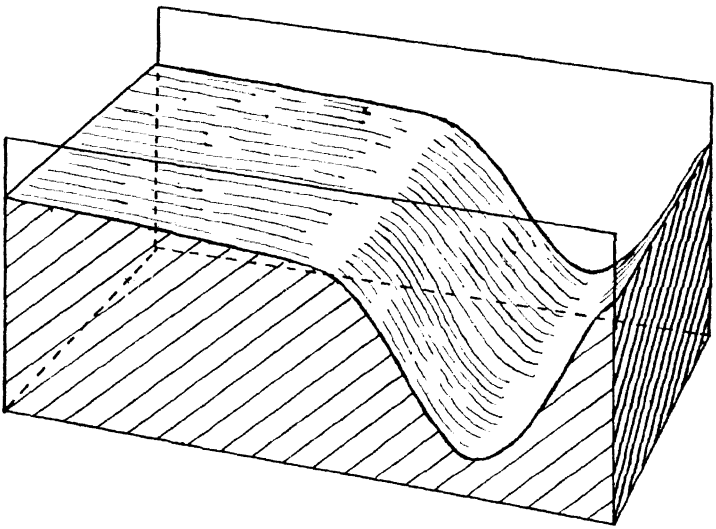


Fig. 43.—Apparatus to demonstrate cold air drainage and katabatic winds.

20 The Climatic Effects of the System of Major Winds

The following method was originally suggested by H. E. Storey in *The Geographical Teacher*, Vol. X, Part 4. A large map of the world is drawn on a blackboard in such a manner that the parallels of latitude are equidistant. A simple cylindrical (*plate carrée*) or part of the sinusoidal would suffice. A frame is prepared as shown in fig. 44. This should preferably be cut from plywood by fretsaw, but a framework of laths would serve quite well. The tips of the arrows depicting the winds should be outlined on the framework if plywood is used. The trade winds can be represented by wooden tips capable of turning when the frame is used for areas where the trades cross the equator.

Pupils could make a miniature frame on these lines for use with their own atlases, provided the atlas contains a map with equidistant or approximately equidistant parallels covering the area being studied. In either case the frame is placed over that part of the map representing the area in question and then moved according to the season over approximately 5° of latitude on either side of the equator. Storey's suggestion that the frame should move from 15°S. to 15°N. is rather excessive, and a total movement of 10° is probably nearer to the average.

The full use of this method demands a considerable amount of qualification on the part of the teacher and, as implied by its author, the limit of usefulness is reached in middle forms.

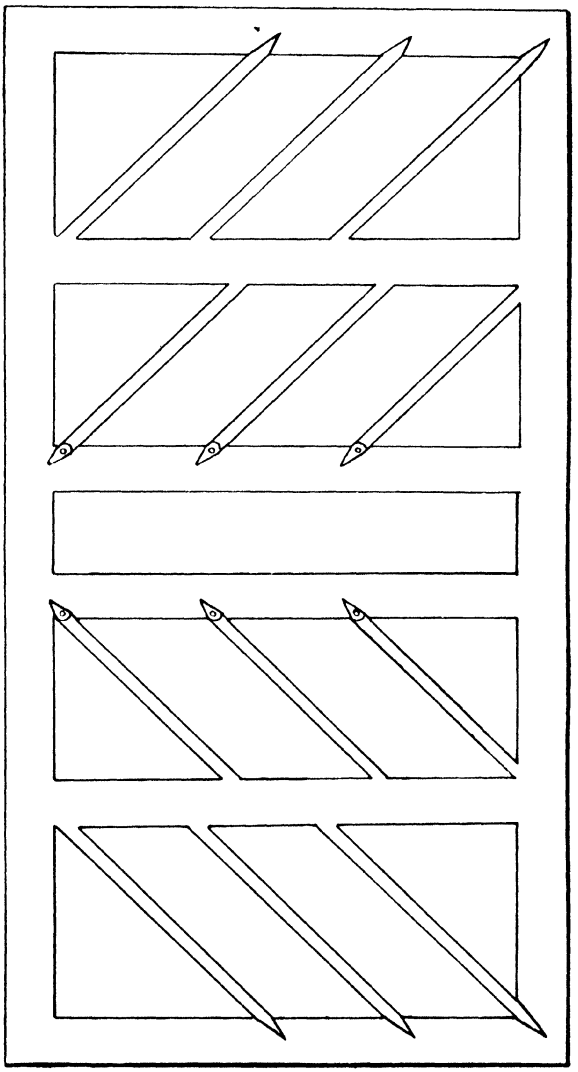


Fig. 44

21 The Movement of the Rain Belts in the Planetary System

The seasonal migration of the latitude of the vertical sun causes in turn a north and south swing of the heat equator and of the planetary system of wind belts. The amount of swing varies somewhat from place to place, but is on the average about 10° of latitude. A model to show the consequential position of the rainy and dry belts, and to indicate the situation of the areas of summer and winter rains, may be constructed from two cardboard disks as follows. On the upper disk—fig. 45 (*a*)—an outline of the west coasts of Europe and Africa is drawn in such a manner that all points are at the correct scale distances from the south pole (i.e. using the zenithal equidistant projection). Since the distortion longitudinally is so great beyond the equator, however, it is better for class purposes to use a conventionalized portrayal as indicated. A strip of cardboard about $\frac{1}{4}$ in. in width is cut away along the coasts to disclose the second disk placed beneath. Parallels of latitude are drawn as desired on the upper disk.

On the lower disk—fig. 45 (*b*)—the rain belts are drawn as concentric rings, but the centre employed lies at 5° N. latitude along the central meridian. The rain belts are shaded or coloured. As the lower disk is rotated around the common axis the rain belts will be seen to move north and south along the west coasts of Europe and Africa over a range of some 10° of latitude. The correct positions for the season should be marked on the lower disk, and these are seen through a slot cut in the upper disk.

The model may be further improved by showing the change in the latitude of the overhead sun. This is obtained by constructing a circle of a radius equivalent to the distance occupied on the diagram by 90° of latitude, the centre being at $66\frac{1}{2}$° S. on the central meridian of the lower disk.

The model is clearly within the ability of most pupils, provided that each step is explained carefully. It will be found helpful, however, if a tracing of the coastal outline is made available for the chosen scale, as this part of the construction may, in certain cases, be found difficult by the pupils.

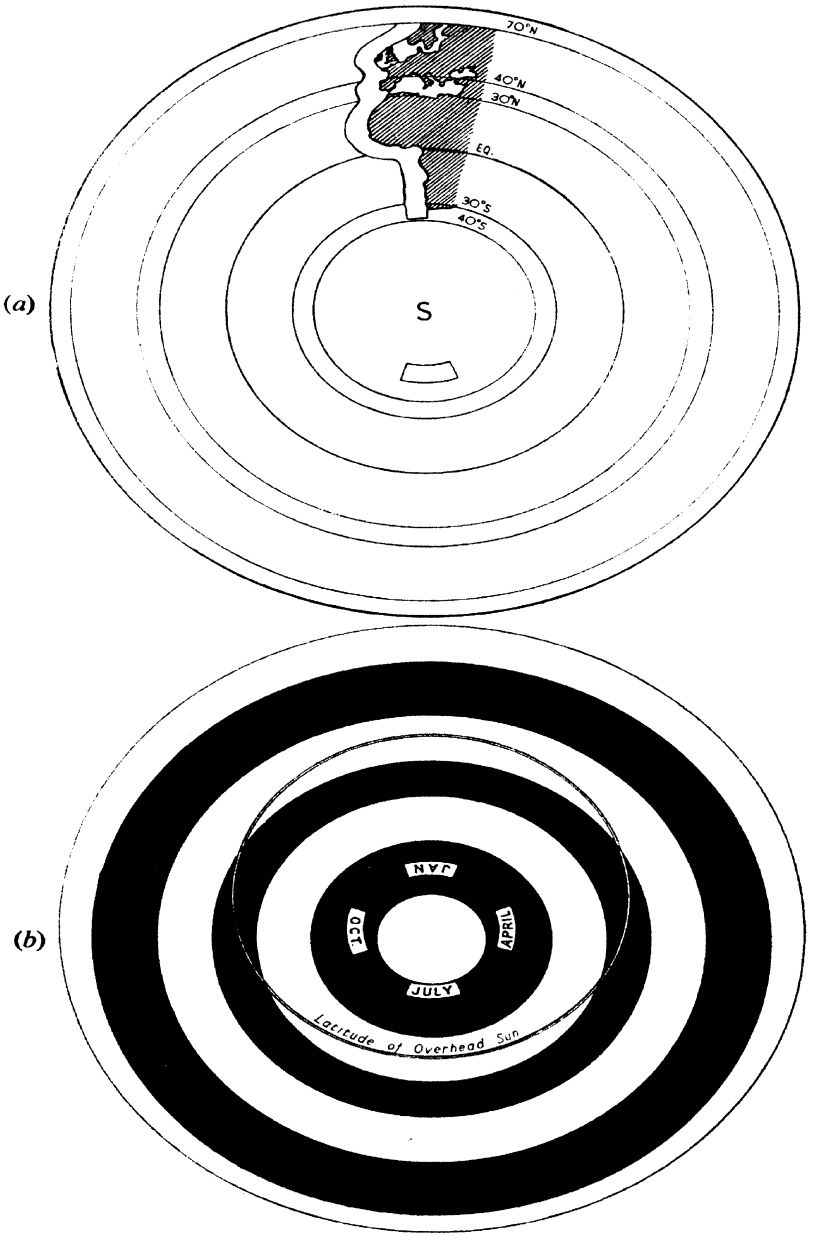


Fig. 45.—Model to demonstrate the movement of the rain belts in the planetary system.

22 Models to Demonstrate Wave Motion

An observer in a boat or on the shore sees a procession of waves moving in a definite direction, but it is clear that the water itself does not move in the direction of the waves as a continuous process. A floating object will be observed to move up and down in a vertical plane: closer inspection will show that the actual path traced out is really orbital—i.e. it has a circular path in which there is a back and forward motion as well as the more obvious vertical motion. The water particles similarly execute an orbital motion and the movement of the wave forward is apparent rather than real. In shallow water the vertical components will be retarded by friction with the sea bottom and the horizontal motions are more conspicuous. When near the shore retardation of the wave may be so great that the upper part falls forward on top of the lower and at this juncture the wave is breaking.

Provided there is sufficient depth, however, the wave motions will progress forward without actually involving a continued displacement of the medium in the direction of apparent movement. All wave motions have this characteristic in common. Thus sound waves which are caused by longitudinal (horizontally backwards and forwards in a line) movements of the air particles progress without involving a wind movement—indeed they may move upwind.

A model which makes the formation of progressive waves due to a simple vertical motion of particles is illustrated in fig. 46. The construction is quite easy, except for the crankshaft, which must be made with great care. The result, however, is well worth any extra trouble taken in the construction, for the effect is quite dramatic. Thick copper wire is recommended for the cranks and shaft, care must be taken to ensure that the cranks are exactly the same length and inclined to each other at 45°. From the numbered diagram it should be clear that the cranks progress in an even spiral round the shaft. The little stirrups, from which hang on threads of equal length table tennis or similar balls, may be made of short lengths of glass tubing. To align the balls the threads are passed through the evenly spaced holes of a Meccano construction strip, whilst short lengths of similar material screwed to the back of the containing box support the crankshaft at suitable points. At least nine balls will be needed to adequately represent one wave-length (as shown in fig. 46 (*a*)) and, if it is desired to represent two waves, seventeen will be found desirable. Fig. 46 (*b*) represents the end elevation of the model and shows the arrangement of the crankshaft for one and two waves respectively. In this diagram some of the smaller parts, e.g. the wire, have been enlarged

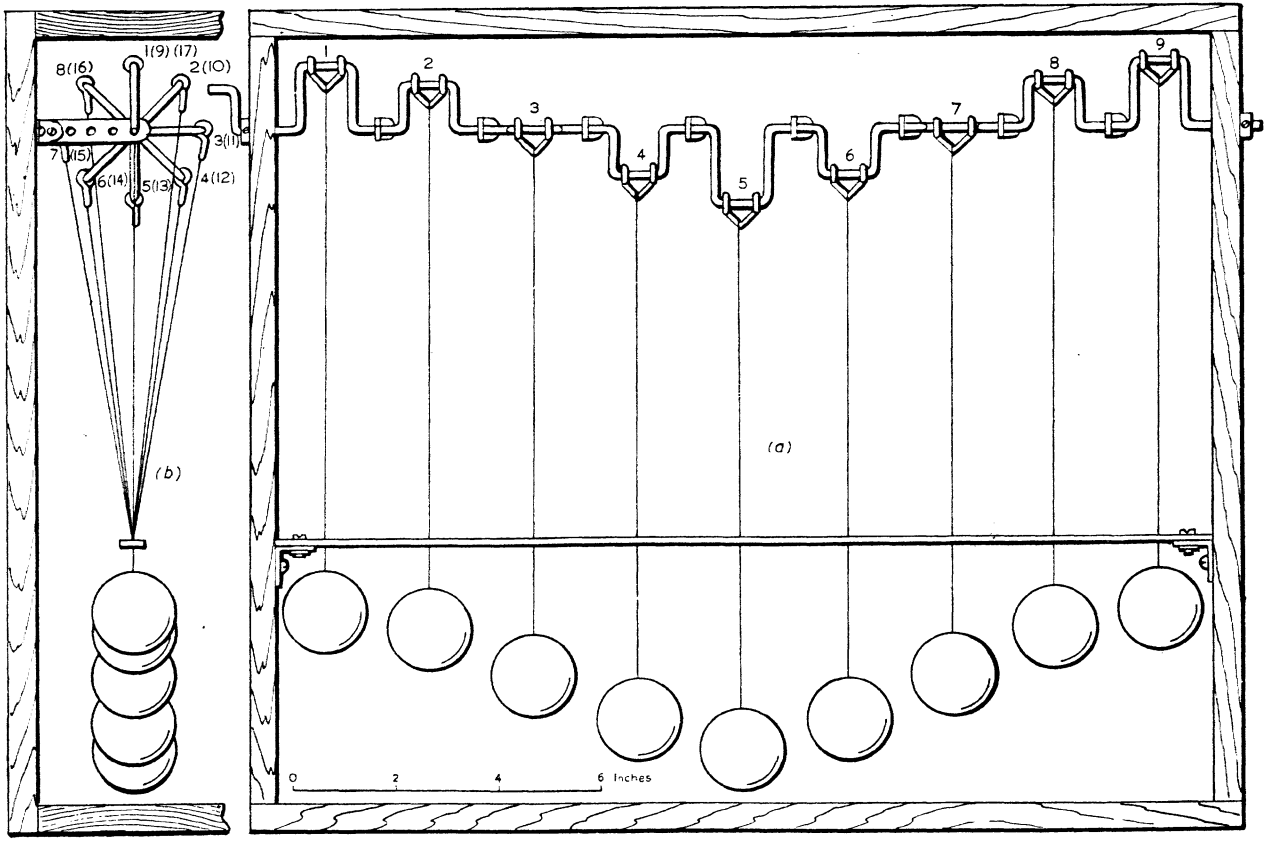


Fig. 46.—Model to demonstrate progressive waves.

for clarity in reproduction. As illustrated the apparatus is a robust construction: a glass front could be added for a permanent model.

After viewing or assisting to make this model, the pupils might construct for themselves the simpler apparatus shown in fig. 47. This is known as Crova's Disk. From the eight successive points on the circumference of a circle of 5 mm. radius, circles are drawn with radii increasing by 5 mm. This is executed on cardboard. When eight circles have been drawn the ninth is inserted with the same centre as the first and the series continued.

The disk is cut out and arranged to turn underneath a rectangular piece of cardboard from which a narrow slit has been cut along the radius of the disk. As the disk is turned around the lines appear to progress along the slit, although if any particular line be chosen and the disk is turned slowly, the line will be seen to move backwards and forwards over a limited distance only.

Finally, a third illustration, which requires no constructional work, would be the wave series which can be made to pass along an ordinary piece of rope held at two ends, one end being agitated.

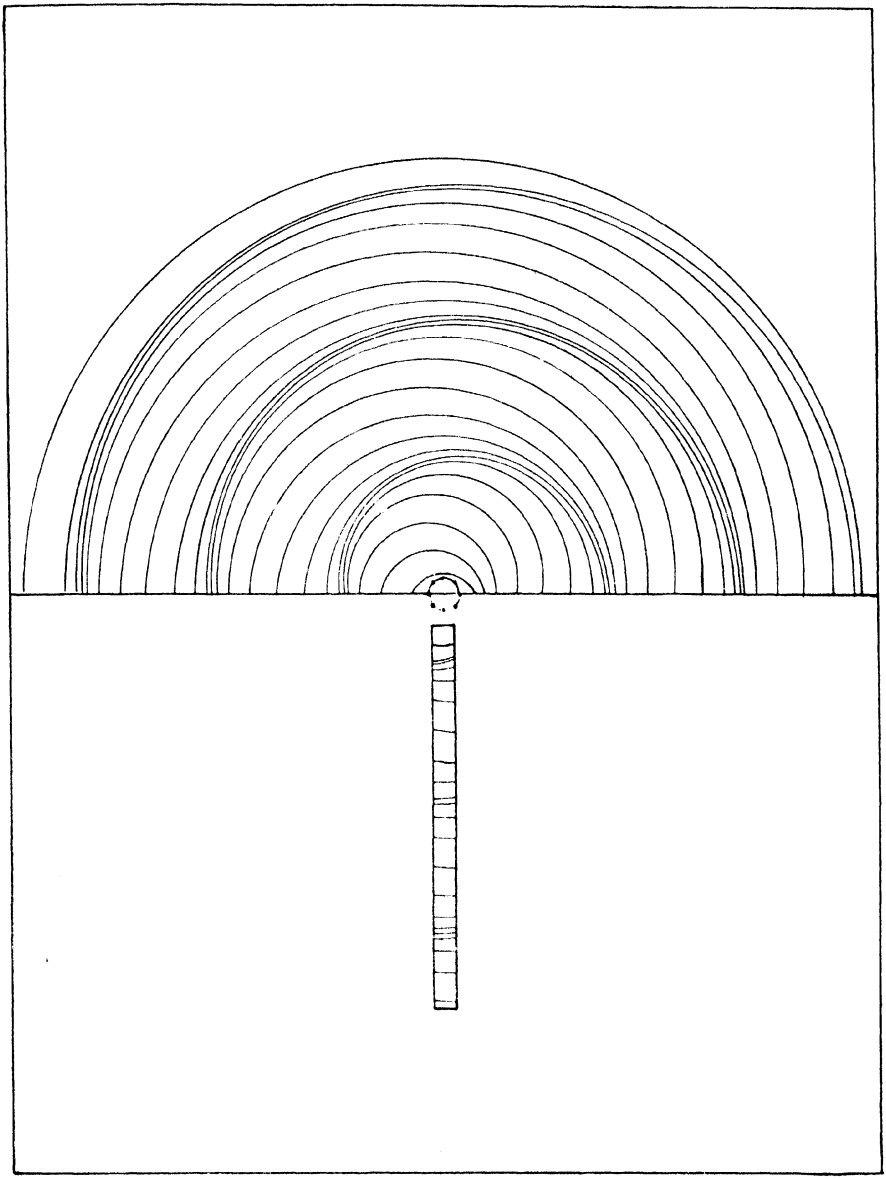


Fig. 47.—Crova's disk, to demonstrate progressive waves.

23 Experimental Demonstrations of Oceanographical Principles

If the teaching of land forms is sometimes difficult because of the unfavourable location of the school (e.g. somewhere in the Fenland), then the teaching of the basic facts relating to the oceans will be a problem for all teachers. At school level the treatment must necessarily be somewhat theoretical and related largely to maps. The greater number of pupils may hence find it difficult to grasp what to them may seem somewhat strange concepts. An experimental approach to the subject may, however, be made with the help of a little equipment borrowed from the physics laboratory. This should not only foster a much greater interest in this vital, if somewhat removed, aspect of world geography: it should also provide something definite upon which the essential facts may be built and remembered.

(a) Ocean Currents

The major ocean currents are, of course, produced by wind action, and the resulting movements are intimately related to the planetary system of winds. The essential mechanism which produces the movement can be easily demonstrated by directing an adjustable stream of air obliquely on to a water surface and, by the use of various markers, watching the movement of the water.

A variety of methods of achieving this suggest themselves. If an earth sculpture tank is available (see p. 53), this could be used to hold the water. Alternatively, a small-scale method might utilize a shallow tank about 3 ft. by 2 ft. in plan and 6 in. in depth. At one end of the tank some land forms may be rapidly modelled—a replica of the Western Atlantic suggests itself as being suitable—and the tank is then filled to a depth of 4 in. with water. The directed stream of air is obtained by means of an electric fan and a fairly long, wide tube which collects the air and conveys it to the desired point of impact with the water, and also at the required angle. This will be at the other end of the tank, the stream of air being directed towards the modelled coast with the point of impact in approximately the 'equatorial' regions.

The resulting movement of the water may be watched by distributing minute, coloured pieces of confetti on the water surface or by introducing drops of aniline at various points and depths. Aniline has a density very

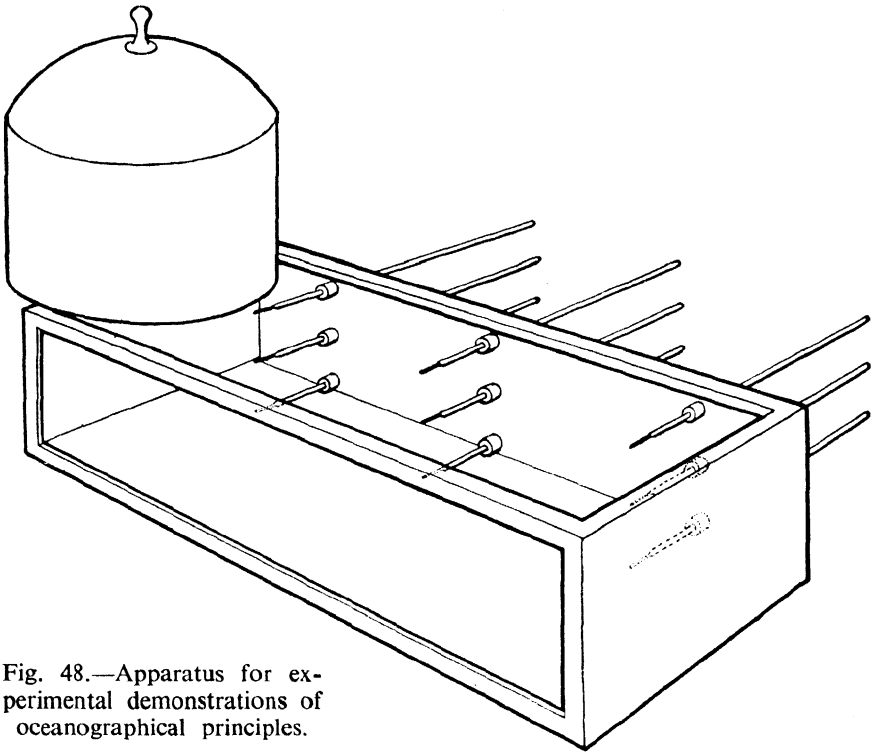


Fig. 48.—Apparatus for experimental demonstrations of oceanographical principles.

slightly greater than that of water and will remain almost suspended wherever it is released. If these drops are used it may be possible to show the upwelling effect which occurs on coasts where offshore winds are prevalent. This type of experiment will demonstrate the essential basis of the origin of ocean currents; it can, of course, be made more elaborate if desired. A more complete replica of the Atlantic might be modelled and more than one air stream used.

(b) Temperature Distributions

The horizontal and vertical distributions of temperature in the oceans may be equally difficult for the average pupil to grasp, but the following experiment should greatly assist in establishing the essential principles. To be effective, a special tank should be constructed; its size should be some 2 ft. by 9 in.

in plan and about 1 ft. in depth, one side consists of plate-glass (to be used in the following experiment) and the opposite long side is of wood with a large number of systematically drilled holes with rubber stoppers to fit. The remaining sides and the base can be of wood, leakage being avoided by the use of ordinary putty. The holes which have been drilled in the long wooden side are to take thermometers inserted horizontally—these being held in place with the usual holed rubber stopper (see fig. 48).

The tank is now filled with water of a uniform temperature and allowed to settle. A beam of heat is next directed at the surface of the water, either at one end or at the centre by means of a shaded electric bowl fire. This simulates heat rays from the sun. Every few minutes the thermometers are read and the results plotted graphically. The slowness with which heat reaches the bottom will be apparent, the surface skin will warm up appreciably and eventually a strong discontinuity layer will emerge.

(c) Deep Water Circulations

The circulation of water within the oceans is largely related to the inequalities in density between different water masses. Differences in density arise because of variations in temperature and salinity. When these differences exist, the denser water will tend to sink until it reaches water of its own density, and here it will spread out horizontally. In special circumstances, of course, the water will sink right to the bottom of the ocean and spread outwards there. To be in a stable condition the density must decrease upwards: this can be achieved by different combinations of salinity and temperature. The wide variations of temperature and salinity which arise in nature do not, however, favour a stable condition, and the ocean waters are continually moving at sub-surface levels in an effort to achieve what is, in effect, the impossible.

The mechanism of these deep-water circulations can be demonstrated with the aid of the glass-fronted tank already described for (*b*) above. The thermometers should be removed and the holes closed. A bag containing ice is hung at one end of the tank and radiant heat is directed on to the surface at the other; the resulting movements of water which will arise through the temperature differences may be watched by a scatter of small confetti on the

surface and by aniline drops, or ink drifts, introduced at various levels for the vertical plane.

Whilst the experiment is under way, the effect of differences in salinity may be demonstrated by releasing gently on to the surface of the water, about midway between the fire and the ice, some saline water coloured with potassium permanganate.

Quick graphic plots or sketches of the water movements should be made at regular intervals for subsequent analysis and discussion.

SECTION D

SURVEY AND MAP PROJECTIONS

24 The Construction of Simple Survey Instruments

IF time allows, considerable interest to introductory work in survey can often be added if the class is permitted to construct some of the apparatus. One cannot expect accurate results with most amateur constructive efforts, but the nature and principles of the instruments will be much more thoroughly understood where pupils have been able to make their own apparatus. Schools possessing wood or metal-working facilities will clearly be at an advantage if work on these lines is contemplated. Co-operation between the respective teachers is essential and may well prove to be to their mutual advantage. Where the school has supplied the materials it will be possible for the teacher to retain the better efforts and gradually build up a stock of useful apparatus.

It is difficult to give precise and detailed instructions, since much will depend on the available materials. Hence in the following pages emphasis has been laid on ideas, with suggestions as to some means of producing workable instruments. A knowledge of the essential principles of survey work is also assumed: if further details are required reference should be made to standard text-books such as Debenham, *Map Making*; Bygott, *Map Work and Practical Geography*; Jameson and Ormsby, *Survey and Map Projection.*

(a) Plane Table Survey

The production of a plane table complete with collapsible tripod and the various accessories will probably appear to be somewhat of a tall order at first glance. The proper survey instruments, however, have been made to satisfy refinements which are not necessary when the principles are being taught. The collapsible table and tripod are essential for ease of transport

in real survey, but the teacher will probably not leave the school grounds, and can in fact do a great deal in the school hall. For a simple and first approach the school hall offers considerable opportunities, and for junior forms this is perhaps to be recommended, in view of the distractions provided by the weather and other outside activities, if the work is attempted in the school grounds.

In the school hall the floor is level and an ordinary four-legged table about 2 ft. by 3 ft. may be used. A simple alidade may be made from a bevelled piece of seasoned oak to which a 12-in. boxwood ruler and two sighting vanes in cardboard or tinplate have been fixed. Chains or tapes prepared in connexion with the chain survey can be used for base measurement. Work in such restricted surroundings will probably involve the necessity of ensuring that the bases on the map are vertically above the chosen bases on the floor. This can be arranged by holding a plumb-bob exactly underneath the bases on the map and moving the table until the bob is over the base on the floor. A spirit-level will not be needed for this simple approach, and it will probably be inadvisable to introduce any form of box compass with the possibility of 'local attraction' deflecting the compass.

For advanced work, the school grounds may be used, but in this case a three-legged adjustable table is essential, together with a spirit-level. A serviceable table which is not difficult to construct in the school handicraft shop is illustrated in fig. 49. The stand consists of a hexagonal piece of $\frac{1}{2}$-in. wood cut from a circle of 4-in. radius. This is supported by three legs 4 ft. 6 in. long, tapering from 4 in. to $\frac{1}{2}$ in. The leg is shown in (*b*) and the stand with legs attached in (*d*). If desired, the legs may be jointed as in (*e*), using 3 in. by $\frac{1}{2}$-in. brass butts, the hinge of which should be no the inside. · Greater security when in use results if a metal skewer be passed through two rings screwed into the leg as at (*f*). The method of attachment of the legs and stand will be clear from (*a*), 3-in. brass butts again being used.

The table consists of a $\frac{1}{2}$ in. thick solid drawing-board secured to the stand by a short bolt with wing nut for releasing the table when desired, i.e. for putting away or turning. The hole accommodating the bolt and washer should be filled in with putty or plastic wood. An alidade with tinplate ends and metal ruler, such as is used in handicraft shops, screwed on to a bevelled strip 12 in. long, is shown in fig. 50. If desired, any tinsmith will provide sighting vanes in stouter galvanized iron to any given pattern.

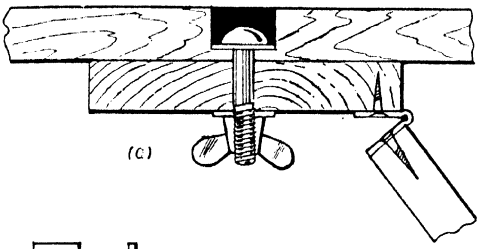
With the aid of the equipment outlined above, the essential principles of plane table survey—intersection, resection, traversing, etc.—can be demonstrated very effectively. Duplication of the apparatus will, of course, enable the class to be broken down into smaller groups and give each pupil a better chance to try his hand at this type of survey.

(b) Chain Survey

The essential instruments in chain survey are the chain, a tape, ranging poles, and arrows. If the school possesses a metal workshop the construction of a simple linked chain will present few difficulties and provides work which can well be undertaken co-operatively by the greater part of the class. The cutting and bending of the rods and links can also be carried out with the aid of some metal-working toys—e.g. Juneero. Each rod should be joined by three links and the exact length can be obtained by opening and closing the links as required. A stronger piece of metal will be needed for the handle and suitable counting tags should be added to the chain to facilitate measurement.

Quite a serviceable tape can be constructed with the aid of a length of white linen tape $\frac{1}{2}$ in. in width. This will need graduating throughout in marking ink. For storage, a 16-mm. film spool will be found to be useful; alternatively, a workable container might be constructed with the aid of a spindle and a circular cheese box.

Ranging poles will present little difficulty—broomsticks staked at one end and marked off in foot intervals in alternate red, white, and black colours will function as well as the proper survey poles. Arrows can be made in either metal or wood.



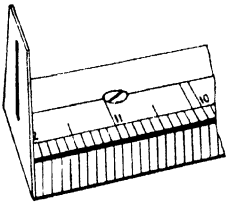
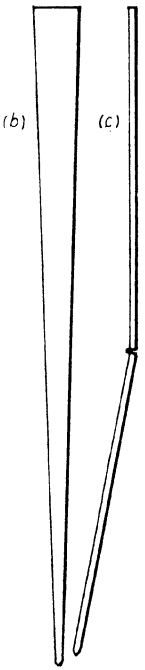
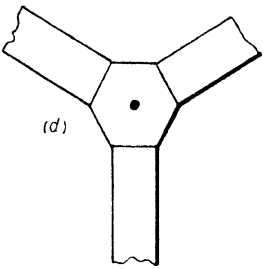


Fig. 50





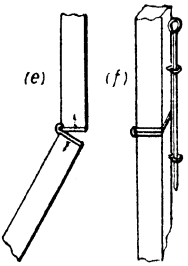


Fig. 49

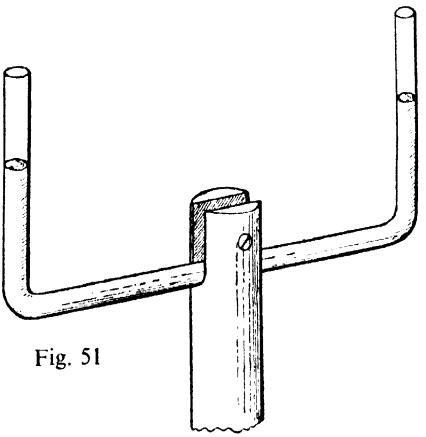


Fig. 51

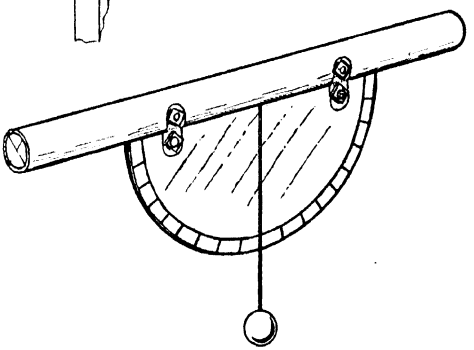


Fig. 52

(c) Levelling

The principles of levelling can be taught without the possession of an elaborate engineer's level or the simple hand-level. The improvisation is based upon the method followed in the use of the simple hand-level. The first piece of apparatus needed is a graduated staff; a long, fairly solid piece of wood with a face of about $2\frac{1}{2}$ in. in width should be chosen and subdivided into feet and tenths (or feet and inches). The elaborate method of subdividing a normal survey staff will not be necessary for reasons which follow below. The level line of sight is achieved by means of a water-level: a wide U-shaped glass tube is part filled with a dark liquid and mounted vertically on a wooden base. This is supported on a suitable broomstick. Alternatively, if the broom-stick is thick enough, the method shown in fig. 51 may be employed. In keeping the tube upright it should not be gripped too tightly. The groove could be packed with material or a metal ring could be fitted over the top of the stick as an alternative to the screw shown. Dust can be excluded from the tubes and the loss of liquid by tipping or evaporation prevented by connecting the two open ends with a piece of overhead rubber tubing.

In use the staff man erects the staff vertically at the agreed station and stands ready to move a pencil up or down the face of the staff. The surveyor with the water-level now looks along the two surfaces of the coloured liquid in the tubes and signals to the staff man to move the pencil. At the instant this comes into view a signal is made to stop. When the pencil is on the line of sight the *staff man* then takes the reading—note that this is, of course, contrary to the normal practice, but is a way of overcoming the lack of a telescope.

This we might imagine to be a backward reading: the process is repeated for a forward reading. The difference between the back reading and the forward reading will give the difference in height between the two staff stations. The process can now be continued and in this way a line of levels may be run between any two points exactly as in the more accurate forms of levelling. For beginners, the method may be more comprehensible if two staves are employed simultaneously: with the man at the water-level this will, of course, involve a party of three.

(d) Traversing

A traverse consists of a connected series of straight lines of which the distances and angular changes are known. The measurement of the angles may be attempted either by the simple model illustrated in fig. 53, which is made of stout cardboard or wood and will give an accuracy to the degree of subdivision of the protractor drawn on the base. Or, alternatively, the prismatic compass may be employed to measure the bearing of each leg of the traverse.

The construction of a proper prismatic compass calls for a skill and facilities which will not be readily available, but the essential function of the prismatic compass can be obtained although without precision. Where an ordinary compass is available the base of the model in fig. 53 may be modified as in fig. 55 to give the magnetic bearing of any leg of the traverse. The base should be graduated from 0 to 360° in an anticlockwise direction, and sighting pins fixed at 0° to 180°. When these are aligned on an object or along the leg, the north pole of the compass will then point to the magnetic bearing. Should the compass needle be small compared with the drawn protractor a thread may be held taut over the needle to facilitate more accurate reading.

The second essential in compass survey is the measurement of distance between stations. Any tapes or chains that have been made for the chain survey (above) can, of course, be used for this operation, but a better, simpler, and probably more accurate method is to count the revolutions of a bicycle wheel and then multiply by the circumference. A 28-in. wheel is preferable since the circumference is exactly 7 ft. 4 in. A piece of white string or tape should be tied around the wheel and the bicycle should be pushed and not ridden. Some cyclometers will, of course, give the number of revolutions from one observation to the next. Failing any of these methods, distances can always be paced. At the end of the traverse the observers should walk up and down a stretched-out tape to find the average length of each individual's pace.

(e) The Measurement of Vertical Angles

The only common survey operation which the preceding notes have not covered is the measurement of vertical angles. A number of instruments are available for this in real survey, ranging from directors and theodolites to indian clinometers and abney levels. The trigonometrical principles involved are, however, common to all instruments, and the only problem is normally the measurement of one or more vertical angles. For sun observations effective use can often be made of shadows, and a simple method of finding the sun's altitude has already been given in fig. 11.

To measure the elevation of any object, however, a sighting arrangement will be necessary. The simplest construction that may be attempted is shown in fig. 54, and this may be employed for both angles of elevation and depression. Pins for alignment on the object may be fixed either horizontally or vertically, but in the latter case care must be taken to see that the heads of the pins, which are aligned on the object, are the same height above the edge of the board.

An alternative method which should appeal to many is illustrated in fig. 52. This consists of a narrow cardboard tube to which is attached a Perspex protractor and plumb-bob. It is necessary to cut away the part of the protractor below the graduations, leaving a semicircle. The protractor may be attached by means of small Meccano parts, as shown, but when a metal tube is obtainable a metal protractor may be soldered into position. In the case of a narrow tube it is sufficient to place cross-wires at one end only, but for wide tubes they should be placed at both ends. A cap with a very small hole may be employed as part of the eyepiece. An observer soon learns to work alone with this type of instrument, but, where help is at hand, a second observer is useful for reading the position of the plumb-bob; the protractor reading will normally be the complement of the angle of elevation of the tube.

Apparatus of this type will enable practical exercises to be undertaken by the class: finding the height of trees, the height of the school tower or clock, etc., can all be employed as a basis for explaining how the height of, say, a mountain is determined in real survey.

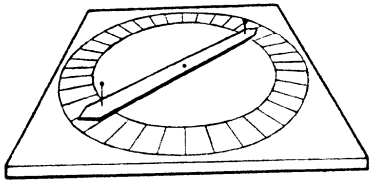


Fig. 53

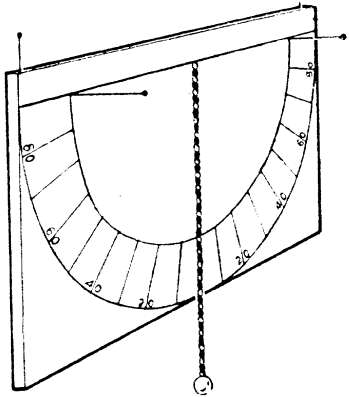


Fig. 54

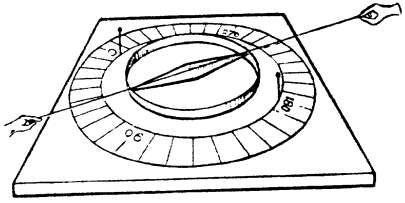
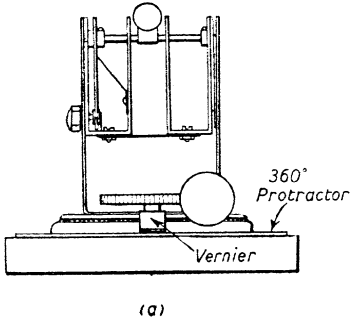
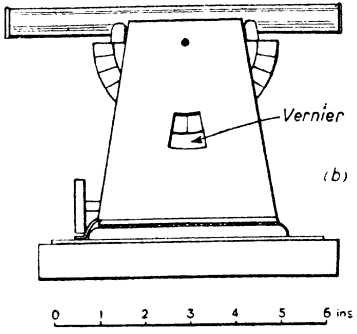


Fig. 55





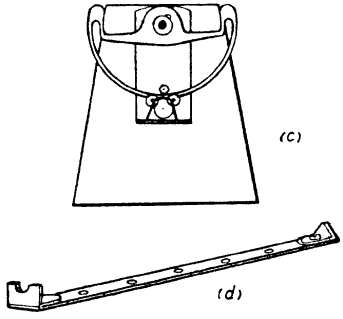


Fig. 56

The interested teacher or pupil will probably desire to improve upon these somewhat simple methods, and with patience it is not at all difficult to construct quite a serviceable theodolite. The model illustrated in fig. 56 was made by a schoolboy using, amongst other things, obsolete radio equipment. These parts are easily obtainable and the task of adapting them to the present purpose would prove attractive to any mechanically minded person. Fig. 56 (*a*) shows a front elevation and fig. 56 (*b*) a side elevation, whilst in fig. 56 (*c*) the inside of the back panel is depicted showing the mechanism for vertical motion.

Horizontal motion was obtained by means of a worm gear, and the body of the instrument was supported on a ball-race, but this is not essential. Vertical motion was controlled by the equipment used to work the tuning condensers of a radio set, the movable protractor being fixed to the axle so turned. Horizontal angles were measured on a circular protractor fixed to the base.

The telescope was made of sheet zinc bent into shape; it was of the astronomical type, since the construction of a terrestrial telescope is difficult for an amateur. An observer soon gets used to an astronomical telescope, but there is the alternative of modifying Meccano parts, as shown in fig. 56 (*d*), to make a sighting bar with rifle-type sights. In the measurements of the angles an excellent alternative to verniers, provided a 360° protractor is used, is an arrangement of Meccano gears to give a ratio of 10:1.

Employing a theodolite of this type, the latitude of the school can be found approximately on any day when the sun is visible. Since the latitude of a place is, in fact, the declination of the zenith of the place, we have only to find the zenith distance of the sun (which is 90° minus its altitude), and add to (winter) or subtract from (summer) this value the declination of the sun (listed for the particular day in the Nautical Almanac) to find the latitude of the place. The observation must, of course, be taken at midday when the sun is on the meridian. In the absence of a nautical almanac the latitude can only be determined approximately on or very near to the equinoxes when the sun's declination is approximately zero.

25 Working Models to Demonstrate Perspective Map Projections

Many pupils when first introduced to the subject of map projection find some difficulty in visualizing the actual projection of detail from the three-dimensional spherical surface on to the two-dimensional plane surface. A demonstration with a working model, however, rarely fails to resolve any difficulty that may be experienced. It will be recollected, of course, that most 'projections' in common use are in fact non-perspective or conventional and cannot be derived as a projection from the sphere in the true mathematical sense of the word. Nevertheless all are so closely related to some form of perspective projection that we may employ the following method with confidence at elementary levels: after the principles have been mastered the refinements can then be considered if necessary. The majority of teachers will be concerned solely with establishing a broad idea of how we can map the surface of the sphere.

There are three major categories of projections, and these are, of course, the *zenithal*, in which the projection takes place on to a plane; the *conical*, where the projection takes place on to a cone which is then cut up one side and laid out flat (or 'developed'); and, finally, the *cylindrical*, where a cylinder is used in place of a cone. It might be mathematically more correct to regard all projections as conical, since the cylinder is really a cone with the apex at infinity and the plane a cone with the apical angle at 180°.

The perspective cases of the three categories can be simply illustrated with the following apparatus. Obtain a large spherical chemistry flask with a long narrow neck, and on the outside of the flask paint thin black lines to represent lines of latitude and longitude. Fix the neck of the flask firmly into a wooden base or hold in a laboratory clamp. Mount a miniature electric light bulb on the end of a stout piece of wire and connect to a suitable battery. Insert the wire with bulb in the neck of the flask until the bulb is approximately at the centre of the flask.

Tracing paper is now obtained and the following constructed:

(*a*) a rigid sheet with the aid of an outside card frame;
(*b*) several different cones, using adhesive tape down the seams;
(*c*) a cylinder with a diameter equal to that of the flask.

If the room now be darkened and the electric light bulb switched on, we are able to demonstrate the following perspective projections:

(*a*) THE GNOMONIC. The rigid sheet of tracing paper should touch at the north pole and the electric light bulb should be at the centre of the flask. The shadows of the black lines marked on the flask will give the gnomonic polar network. A spare circle of wire the same diameter as the flask can be used to show how all great circle courses are straight lines on this projection.

(*b*) THE STEREOGRAPHIC. The rigid sheet remains at the north pole, but the light source is removed to the south pole. The closing up of the parallels will be obvious as this operation is carried out. A small circle of wire sliding over the surface of the flask will demonstrate the rather peculiar property associated with the stereographic projection that *any* circle on the sphere will be shown by a circle on the projection.

(*c*) EQUATORIAL AND OBLIQUE CASES of both the gnomonic and stereographic projections can be demonstrated by moving the plane sheet so that it touches on the equator or in any chosen oblique position.

(*d*) THE PERSPECTIVE COCIN. The light source is moved to the centre and one of the cones is placed upon the flask with its apex vertically above the north pole. The projected lines of latitude and longitude are sketched in in pencil on the paper cone. The latter is then removed, cut along a meridian, and laid out flat. A series of cones will demonstrate the different effects obtained by using varying standard parallels.

(*e*) THE PERSPECTIVE CYLINDRICAL. The light bulb remaining at the centre of the flask, the cylinder is now dropped over the flask such that it touches along the 'equatorial' line. The projected lines of latitude and longitude are drawn in in pencil on the cylinder which is then removed, cut along one meridian, and laid out flat.

An alternative to the flask with its painted graticule is a wired network of lines of latitude and longitude. This is slightly more elaborate, but when made in polar hemispheres, can also be used to demonstrate the orthographic projection if a directed beam be obtained from a more powerful light source at the far end of the room.

Models of this kind will clearly demonstrate the essentials of the purely perspective projections: once the idea has been grasped by all pupils, then the modifications which give the non-perspective and conventional projections can be considered with confidence. Interest can be added to this approach by encouraging the class to make several models in groups.

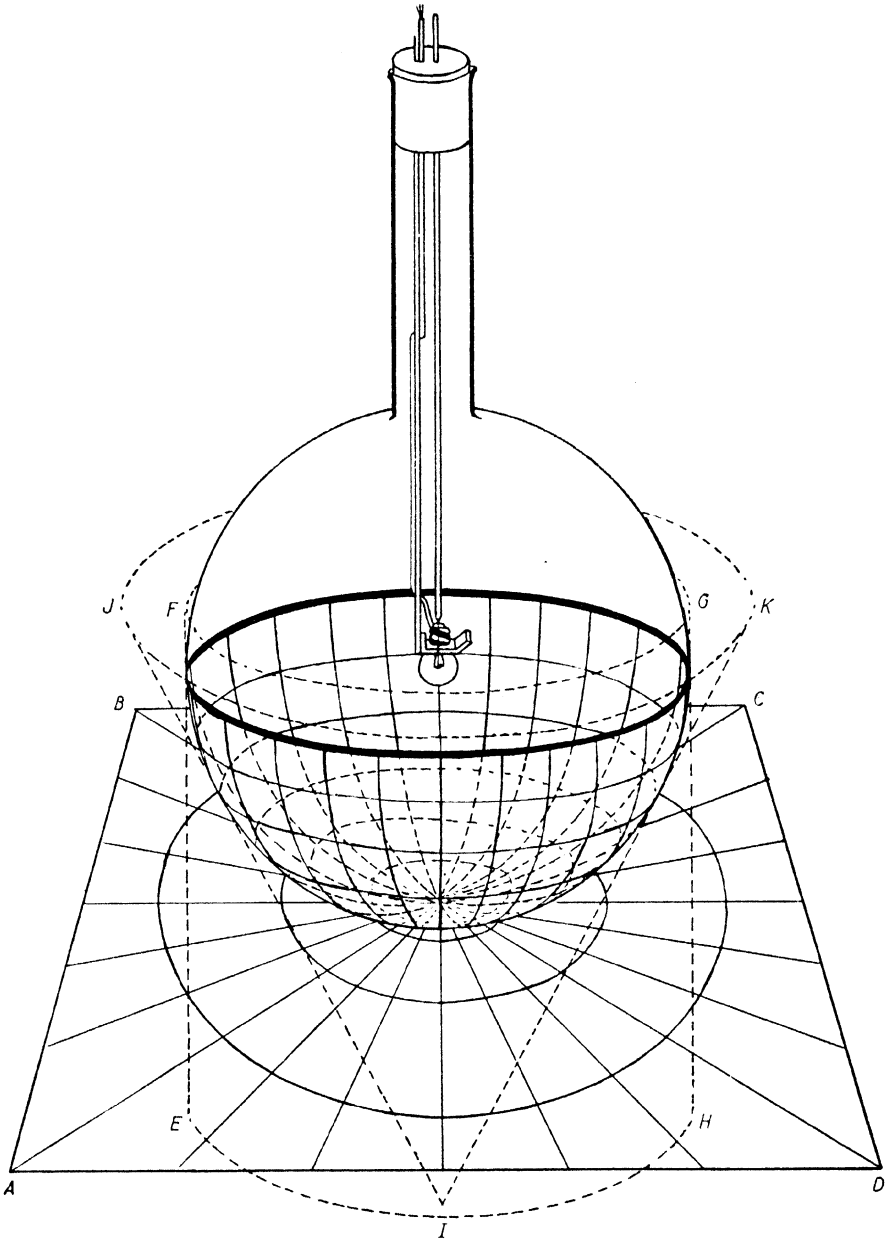


Fig. 57.—A working model to demonstrate perspective map projections.

26 Magnetic Variations

A clear understanding of this subject by young pupils is a necessary prelude to efficiency in map reading and surveying. A very simple approach to the problem is illustrated in fig. 58. A map of part of the northern hemisphere is first drawn on stout paper and gummed to a board, preferably circular and about $\frac{1}{2}$ in. thick. A number of holes, shown by the black circles, are drilled through the board. The central hole is designed to enable the board to fit on to a wooden laboratory burette stand whilst the smaller holes (bored on a circle about 17° from the pole) serve to hold a round-section bar magnet. The magnet is supported, south pole uppermost, in the holes by a close-fitting cork or wooden ring. A small cardboard protractor graduated to read every 10° is also used. At its centre is a small hole and on it is marked a circle equal in diameter to the watch compass used. The compass can then be placed at any desired point on the map. It will point to the magnetic pole as represented by the bar magnet and the magnetic variation or declination at that point can be measured by the protractor.

In order to illustrate present conditions the bar magnet is placed in the hole nearest to the current position of the magnetic pole. East, west, and zero variations can easily be demonstrated and, if required, isogonic lines may be drawn and compared with the standard map. The decreasing value at London may be demonstrated by placing the magnet in successive holes towards the east as indicated by the arrow on the diagram.

In constructing the map the gnomonic projection is preferable as, owing to the flat nature of the apparatus, a lower value will be given at London than is actually the case: the gnomonic projection will help to counter this error. A further modification would be the use of a dip needle to demonstrate the change of dip. The needle will be sufficiently above the map to render it unnecessary to lower the magnet below the hole, though this would be nearer to actual conditions.

As the compass needle operates in the combined field of the earth and the bar magnet, it is desirable to rotate the board until the needle lies in the magnetic meridian, i.e. the bar magnet is to the magnetic north of the needle. In this way the effect of the earth's field is eliminated and the observed variations are more accurate.

The actual conditions on the globe are, of course, somewhat more complicated, but for elementary instruction the suggested apparatus should prove very satisfactory.

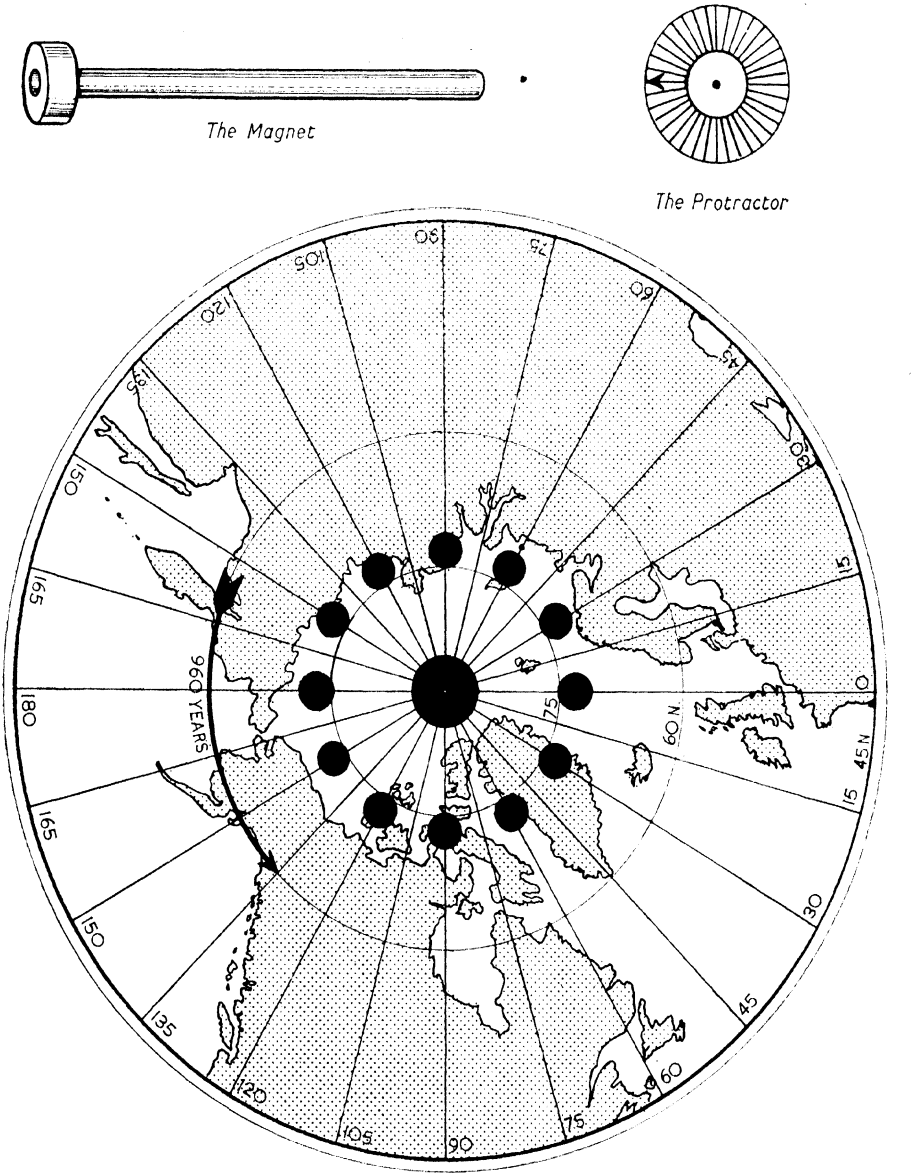


Fig. 58.—A model to demonstrate magnetic variation.

SECTION E

DISTRIBUTION MAPS AND CARTOGRAMS

THE geographer will be concerned above all else with maps and diagrams, not only as aids to instruction, but more especially as essential tools in his craft. And since the best way to a full understanding of the map and cartogram lies in the construction of actual examples, practical work on these lines will normally figure to a large extent in any well-planned course. At the professional level there is a considerable body of information dealing with the construction of distribution maps and cartograms, and in the correct choice of methods and materials. We shall not now, however, enter into an exhaustive treatment of this subject, but rather confine our attention to an outline of the main categories followed by an indication of some practical constructional methods. Some suggestions will doubtless be familiar, but it is thought that others have not yet appeared in any geographical literature.

27 Distribution Maps

I. Non-Statistical Distribution Maps

Most distribution maps can be classified into one or other of two major groups. In the first come the more simple non-statistical areal distribution maps which are well represented in most atlases. The common topographical map is such an example and largely calls for a careful and appropriate choice of conventional symbols. Simple location maps may be prepared on a dot basis without attempting to show quantity or density, e.g. a location of coal-mines without indicating output. Other non-statistical maps usually involve boundaries which on the map at least are clearly defined, as, for example, the distribution of geological, vegetational, political, and religious

data. In many cases a suitable method of differentiation is essential for an effective map, and this can be achieved by one of two methods:

(*a*) COLOUR. This is a very common and effective method. Light colour washes may be superimposed on detail previously drawn in black waterproof ink, bearing in mind that the colours may need grouping, as on geological maps; or may need sharp definitions, as on political maps; or may perhaps need to be correlative with the nature of the data being represented, as on a vegetation map.

(*b*) LINE SHADING. This is an alternative to colour and involves the use of varying shades of monochrome to achieve differentiation. This may be obtained by the use of lines alone at varying widths apart or by combining lines with open dots, close dots, cross rulings, and solid patterns. Fig. 59 below gives an example of the graduations of tint obtainable from patterns of lines and dots.

Fig. 59.—Line shading.

With this method one can rarely show other detail under the line shading, and this restricts its use. If the distributional pattern calls for a large number of differentiations it may be possible to combine both colour and line shading.

II. Statistical Distribution Maps

The second major group embraces those maps where the main object is to portray information which is otherwise only available in statistics. This group may be further subdivided into several categories as follows:

(*a*) CHOROPLETH MAPS. These show simple distributions involving direct ratios and percentages (e.g. sheep per county), and in which the demarcations are usually well defined. Data are usually available for states, countries, counties, etc., in a straightforward manner and the areas corresponding to

the quantities, ratios, or percentages are differentiated according to a predetermined scale. Both the line shading and colour method may be successfully employed. Attention should be drawn to the need for a correct numbering of any scale of tinting, especially when the range is small. This should run in the fashion 0–9, 10–19, 20–29, etc., in contrast to the 0–10, 10–20, 20–30, etc., found on isopleth maps (see below.) In the choropleth map the change in tints demarcates boundary lines and not density lines. Many authors have failed to realize this point and frequently textbook-maps will be found to be in error in this respect.

It should also be noted that choropleth maps may frequently give an incorrect impression, since the quantities being represented are rarely evenly distributed. Thus, if crop production per acre of, say, rice were being shown in tropical lands a false impression results by tinting the whole of Egypt the appropriate colour, and yet in the circumstances this would have to be done. Choropleth mapping is illustrated in figs. 60 and 61. Both maps show the same set of statistics, but in different ways, and a comparison shows readily how different impressions result from the two methods employed. This difference arises particularly where the areas vary considerably. The more correct impression is probably given by fig. 61, where the density of negro population per state, rather than the actual number per state, is presented. A better result also follows if the densities are graded in geometric progression, as is often attempted on isopleth maps. The method is, however, never entirely satisfactory, for conditions within each state are incorrectly represented, e.g. the relatively high concentration in the south-east of Texas is completely lost.

For comparative purposes the actual figures of negroes per state in the 1940 census were as follows:

Alabama	983,290	Iowa	16,694
Arizona	14,993	Kansas	65,138
Arkansas	482,578	Kentucky	214,031
California	124,306	Louisiana	849,303
Colorado	12,176	Maine	1,304
Connecticut	32,992	Maryland	301,931
Delaware	35,876	Massachusetts	55,391
Distr. of Col.	187,266	Michigan	208,345
Florida	514,198	Minnesota	9,928
Georgia	1,084,927	Mississippi	1,074,578
Idaho	595	Missouri	244,386
Illinois	387,446	Montana	1,120
Indiana	121,916	Nebraska	14,171

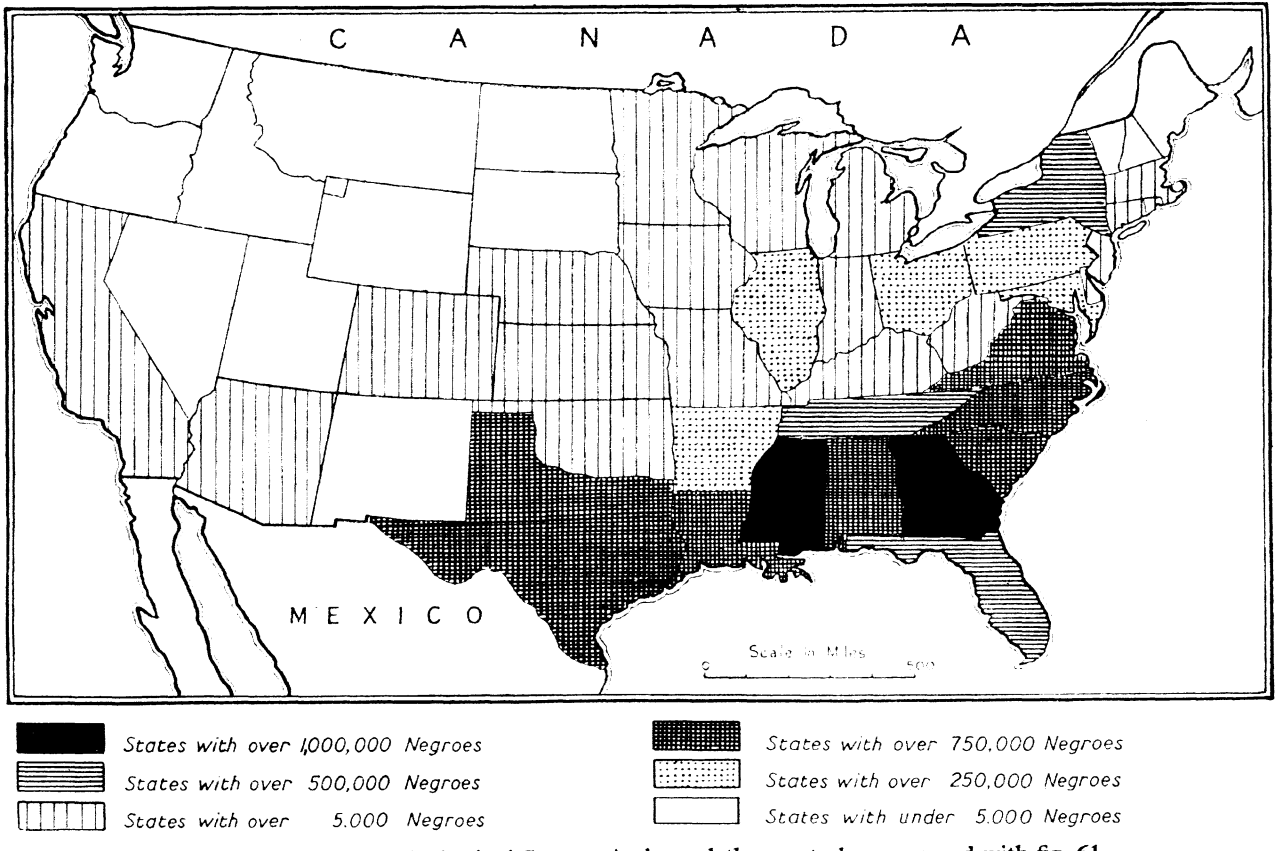


Fig. 60.—Negroes in the United States. A choropleth map to be compared with fig. 61.

Nevada	664	South Carolina	814,164
New Hampshire	414	South Dakota	474
New Jersey	226,973	Tennessee	508,736
New Mexico	4,672	Texas	924,391
New York	571,221	Utah	1,235
North Carolina	981,298	Vermont	384
North Dakota	201	Virginia	661,449
Ohio	339,461	Washington	7,424
Oklahoma	168,849	West Virginia	117,754
Oregon	2,565	Wisconsin	12,158
Pennsylvania	470,172	Wyoming	956
Rhode Island	11,024		

(*b*) DENSITY-DISTRIBUTION MAPS. In this group an attempt is made to show density and distribution accurately. Maps showing population, rainfall, temperature, crop density, and many other quantities fall into this category. Of the various methods which exist the most useful are:

(i) *Isopleth maps.* An isopleth is a line joining equal values in the data being shown. For this reason some cartographers prefer to use the term 'isoline'. In construction the values being represented are plotted on the map in their correct positions and the isopleths are drawn in at convenient intervals. Normally the lines are mechanically inserted on the assumption that values are changing in arithmetic progression. Sometimes, however, an effort is made to interpolate the lines more accurately in the light of subsidiary information, as, for example, the influence of relief on rainfall when plotting isohyets. The isopleth interval must be chosen carefully and in conformity with the scale of the map and preciseness of the data. The method both gives and demands exact information and where the latter is not available isopleths should not be used. The best result is probably obtained where the distribution is fairly transitional, difficulties may arise for widely variable elements such as densities of population.

When drawn, the appreciation of an isopleth map may frequently be improved by the use of either colour or line shading. If colour is used care may be necessary to avoid the impression of sharp steps in the sequence. The distribution of population, relief, etc., will usually call for a graduated colour scheme based on the chromatic scale. On the other hand, a change in the isopleth scale (e.g. much increased rainfall on upper slopes) can be brought out by a definitely arranged colour break or step. The same general

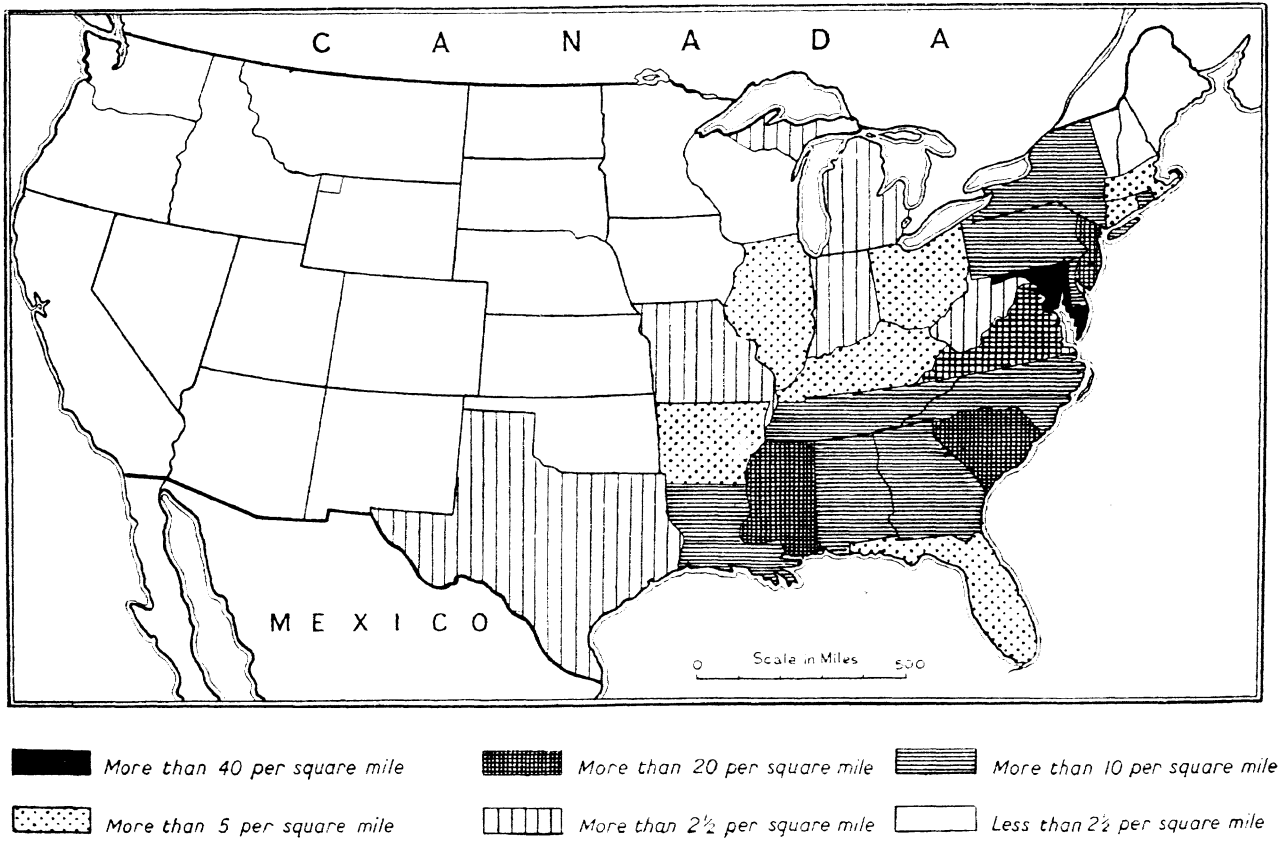


Fig. 61.—Negroes in the United States. An alternative choropleth map to fig. 60.

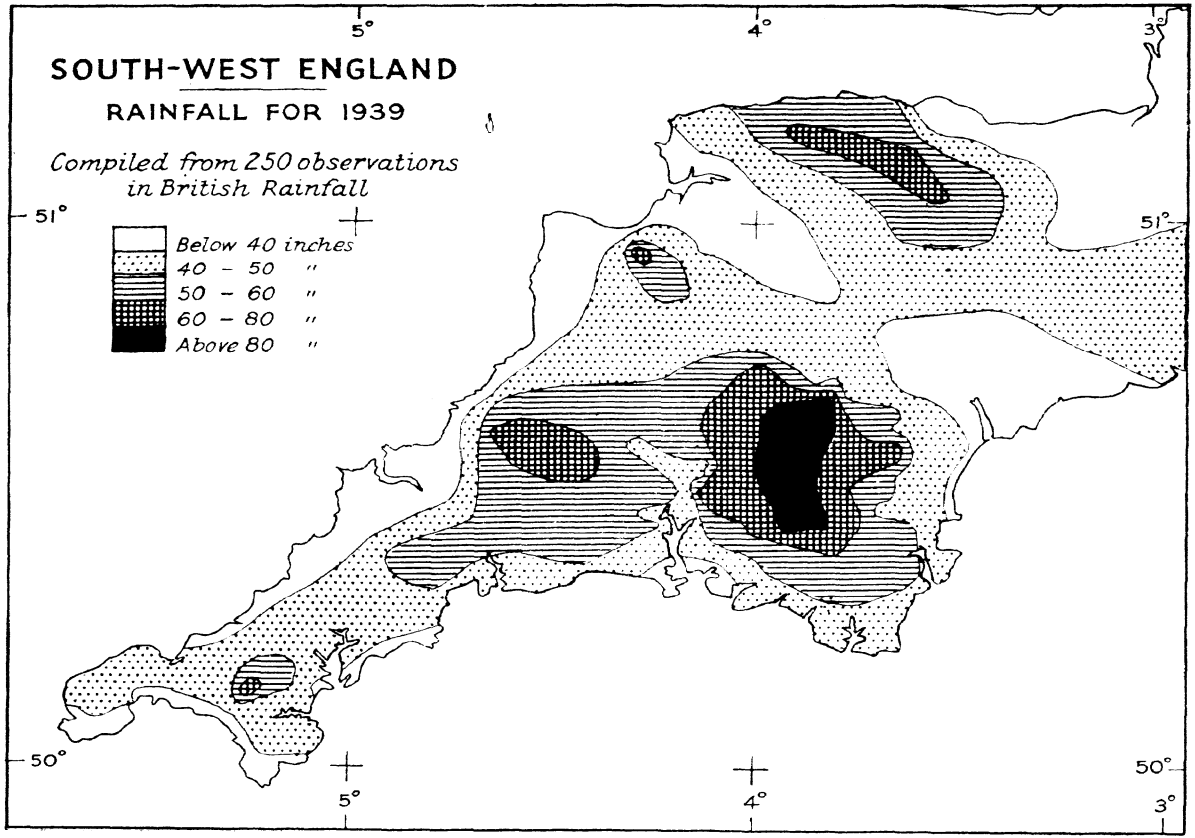


Fig. 62.—An isopleth map.

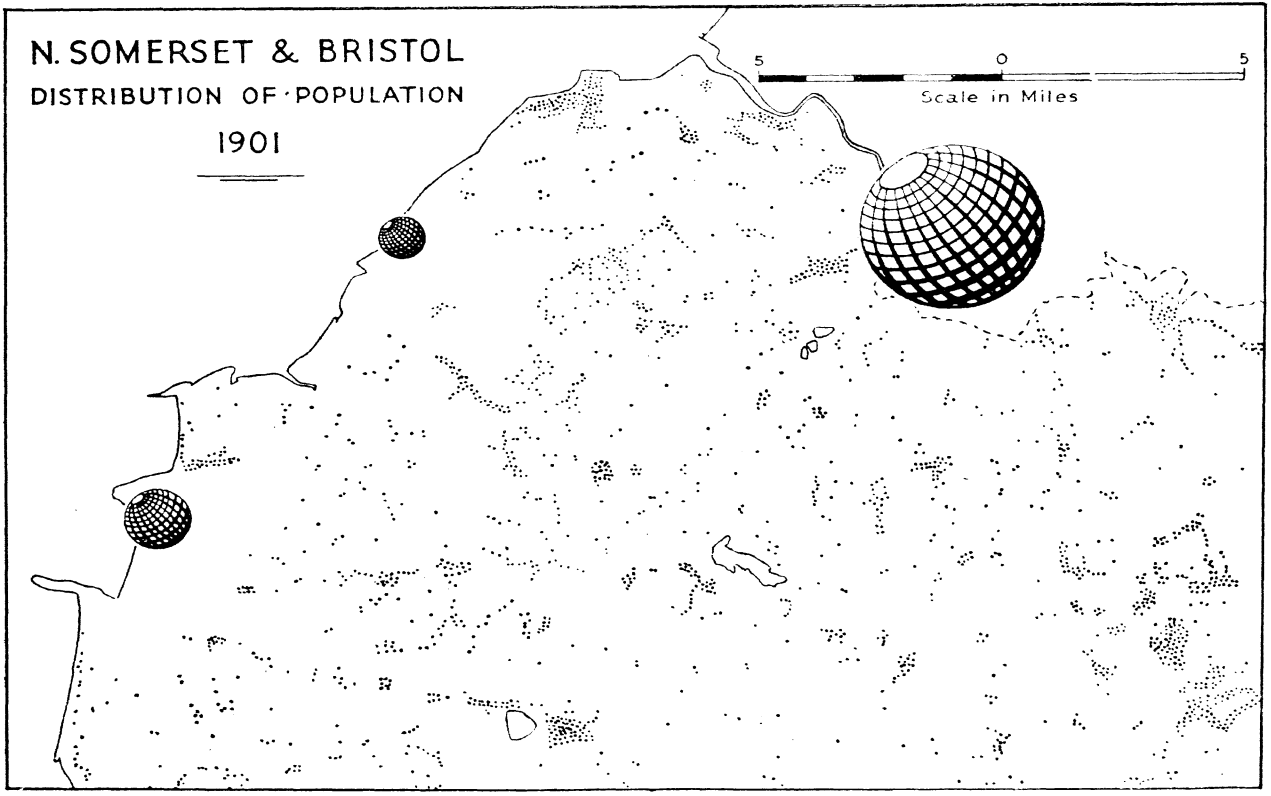


Fig.63.—A dot map. In the rural areas each dot represents and locates 25 persons. In the denser urban areas population is shown by spheres, the diameters of which are proportional to the cube roots of the respective populations (Bristol 330,000, Weston-super-Mare 18,000 and Clevedon 6,000).

principle holds good for line shadin g, but here it is usually easier to arrange for gentle grades or sharp changes as the need arises.

A simple example of an isopleth map is given in fig. 62, where the rainfall isohyets for south-west England in 1939 have been drawn. This map has been constructed with the mechanically ruled Zip-a-tone transfers (see below), and may be compared for finish with figs. 60 and 61, which were hand-drawn.

(ii) *Dot maps.* In distribution maps of this type the density is immediately given by the distribution of dots of uniform size, each dot portraying a given quantity of people, stock, crops, output, etc. Properly constructed maps of this type more truly represent the actual distribution on the ground. There is less dependence on a key and the map can be read more quickly. The chief difficulty is the inability to read off actual values in figures. The success or failure of the map depends mainly on the right choice of the value chosen for each dot. Normally, only one variable is plotted on a dot map, but if distributions are widely spaced more than one variable can be shown by dots of different shape or colour. All dot maps should be clearly based upon equal area projections.

In most cases, as, for example, the distribution of sheep, cattle, crops, etc., the construction of a dot map is fairly straightforward, but population presents a problem when urban agglomerations exist in close juxtaposition to sparse rural distributions. Two solutions have been proposed for this difficulty. In the first or 'areal' case the urban population is shown by means of lightly tinted circles, the radii of which are proportional to the square roots of the respective populations. Within these town circles, satellite towns and rural populations can still be shown. Alternatively, there is the 'volumetric' approach in which small spheres represent urban populations, the diameters of the spheres being related to the cube roots of the populations represented. Although often difficult to achieve, both circles and spheres should, if possible, grade at the lower end of the scale into the dots used for the rural population. Thus, if the urban areas are being represented by 'areal' symbols, cities of 160,000, 90,000, and 40,000 will be shown by circles with radii proportional to 4, 3, and 2. If the largest city is shown by a circle of 4 mm. radius, then a normal dot having a radius of about 0·3 mm. should, if possible, represent a rural population of the order of 1,000, since this approximates to its correct value on the scale. A large range in values may, however, make this difficult.

An example of a dot distribution map is given in fig. 63, which shows the distribution of population in the North Somerset and Bristol area for 1901.

28 Cartograms

The geographer will frequently find the need to express statistics graphically other than in map form and a variety of methods are available. These have been variously called diagrams, charts, graphs, etc., but are perhaps best known collectively as cartograms. Their use is in the main associated with attempts to portray time distributions rather than space distributions; on occasions, however, cartograms will be found superimposed on maps in an effort to combine both the time and space factors. Brief notes are given on the chief methods before turning to the constructional hints.

(a) Circular Diagrams

Data is here shown by a series of circles, the area of each being proportional to the element being represented. Diameters of the circles should therefore be proportional to the square roots of the quantities. The method enables subdivision of the quantities to be shown by sectors of the circles. Colour or line shading may be employed to differentiate the data if desired.

Fig. 64 illustrates the technique and shows for comparative purposes the imports and exports of food, drink, and tobacco in the United Kingdom in 1948. The total values have been subdivided into the following categories, and for reference the actual figures are appended:

	Values in £1,000's	
	Imports	Exports
Grain and flour	201,279	4,039
Other foods	140,136	40,553
Dairy produce	132,052	1,447
Meat	125,652	738
Beverages, cocoa	113,395	28,570
Fruit and vegetables	96,633	1,592
Tobacco	42,845	16,758
Animal feeding stuffs	23,784	301
Living animals for food	11,775	2
Totals	887,551	94,000

(b) Rectangular Diagrams

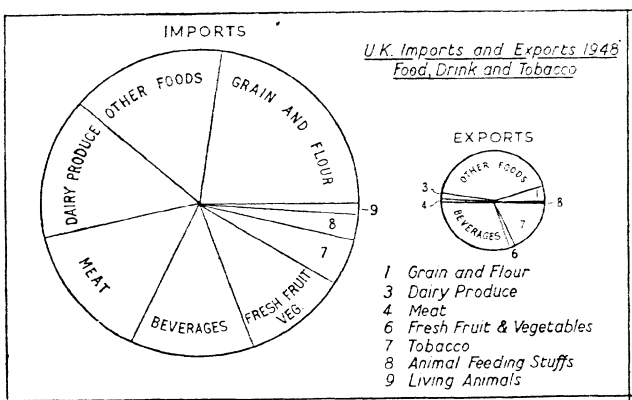
This system is useful for the simple comparison of quantities; bars or rectangles of equal width and drawn to a given scale represent the data being portrayed. As with the circular diagrams, each rectangular diagram can be split up into subdivisions or percentage amounts. The bars may be horizontal or vertical, and colour or line shading may be employed as aids to facilitate interpretation.

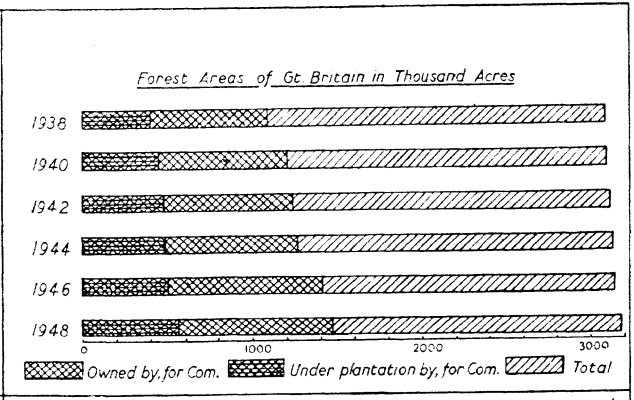
As an example, the acreage of forest areas in Great Britain from 1938 to 1948 is shown in fig. 65, with the amount owned by the Forestry Commission, and under plantation by the Forestry Commission, distinguished from the total. The actual figures in thousands of acres were as follows:

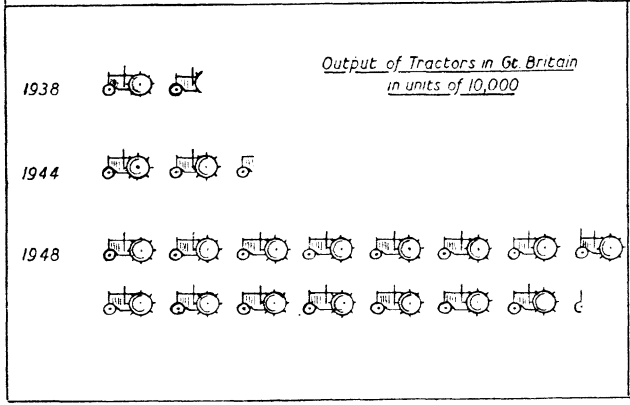
	Total	Owned by Forestry Commission	Under plantation by Forestry Commission
1938	3,045	1,097	403
1940	3,089	1,212	451
1942	3,121	1,237	485
1944	3,136	1,270	494
1946	3,145	1,415	507
1948	3,186	1,477	569

Fig. 64.—Circular diagrams.

Fig. 65.—Rectangular diagrams.







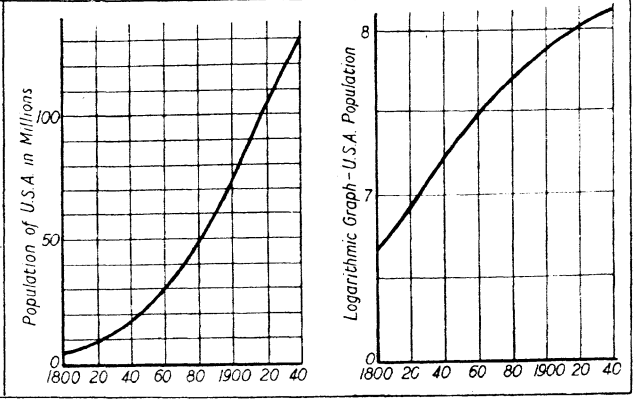


Fig. 66.—Pictorial representation.

Fig. 67.—Mathematical graphs.

(c) Pictorial Representation

Countable pictorial symbols may be used to illustrate statistics; thus a row of 10½ cars might represent an output of 1,050 cars if each car signifies an output of 100. This type of illustration may often be found in elementary text-books and also in Government reports intended for public consumption. An example is given in fig. 66 where the output of tractors in Great Britain from 1938 to 1948 has been illustrated by pictorial symbols. Each picture tractor represents an output of 10,000. The actual figures were as follows:

1938—10,679; 1944—23,059; 1948—150,692.

Pictorial representations may also be used in another way, but in unskilled hands can give rise to erroneous impressions. Thus the output of milk per month might be illustrated by black silhouettes of different-sized cows, but if this is done the length of each cow should be proportional to the square roots of the quantities, since we are really comparing areas. Similarly, if the pictorial figure has an apparent three-dimensional form, then cube roots must be employed. This is a frequent source of error which will be found in many text-books.

(d) Mathematical Graphs

A large variety of graphs have been proposed and employed at various times, but the geographer will usually be concerned with two groups only. The first is the simple line graph in which two variables are plotted true to scale, one of the variables usually being time. The simple line graph resembles the bar graph, but is to be preferred when continuous changes are being represented, for example, temperature and pressure as compared with discontinuous changes such as rainfall, output, price structures, etc. It is most important that the whole of the line graph, including the zero, should be shown. Amputation of the bottom will give a completely false impression of the variability.

For long time-periods recent figures may be very large in comparison with early figures, and a simple line graph would then involve extremely long ordinates. The second category of graph overcomes this difficulty: this is the logarithmic line graph in which the logarithms of one variable are plotted instead of the actual figures, although the latter values may be subsequently affixed to the logarithmic scale. This has the effect of squashing down the top of the graph, since the logarithm of 10 is 1, 100 is 2, and so on. On the other hand, the logarithmic scale has the great advantage of enabling the rate of increase to be seen at a glance. A straight line indicates a uniform rate of increase, a concave curve an increasing, and a convex curve a decreasing rate of increase. This type of graph is useful in population studies, and an example is given in fig. 67 where the total population of the United States from 1800 to 1940 is shown first by means of the simple line graph, and, secondly, by means of the logarithmic line graph. Although the population has gone on increasing, the second graph reveals that the increase is at a diminishing rate. The actual figures were as follows:

1800	5,308,483	1880	50,155,783
1820	9,638,453	1900	75,994,575
1840	17,069,453	1920	105,710,620
1860	31,443,321	1940	131,669,275

For extensive work commercial semi-logarithmic paper may be purchased, the occasional graph, however, can be built up as indicated.

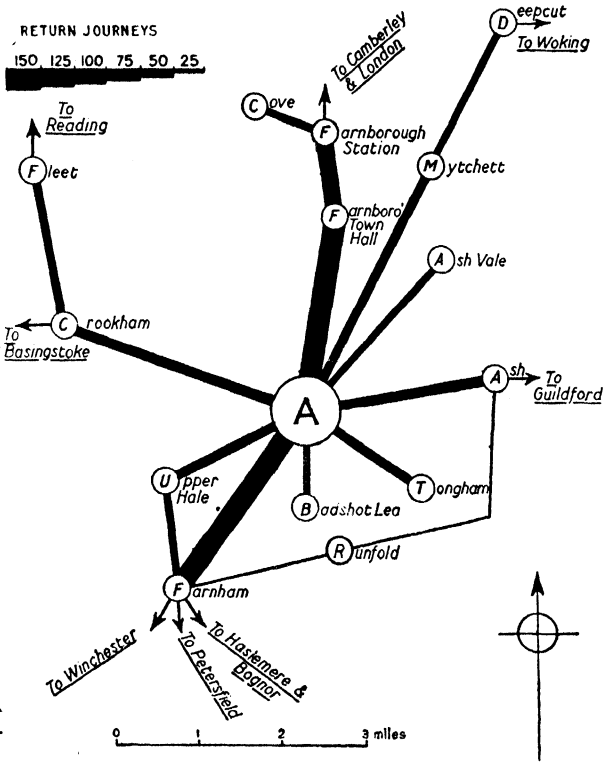


Fig. 68.—A flow diagram.

Local bus services in and near Aldershot on weekdays

(e) Flow Diagrams

In contrast to those maps which express static conditions there are 'dynamic' maps which attempt to show movement. Diagrams to illustrate road, rail, air, and sea communications, migrations and the movement of people, goods, etc., may be conveniently referred to as flow diagrams.

In the traffic flow diagram the thickness of the lines of movement are made proportionate to the amount of traffic they carry. This will involve considerable generalization, such that the representation becomes a cartogram rather than a map. Large insets may be necessary for crowded centres, whilst small figures of the actual values involved may be written against the lines to assist in interpretation. An example of the method is given in fig. 68, which shows the frequency of the local bus service in and near Aldershot, Hampshire, on a normal weekday.

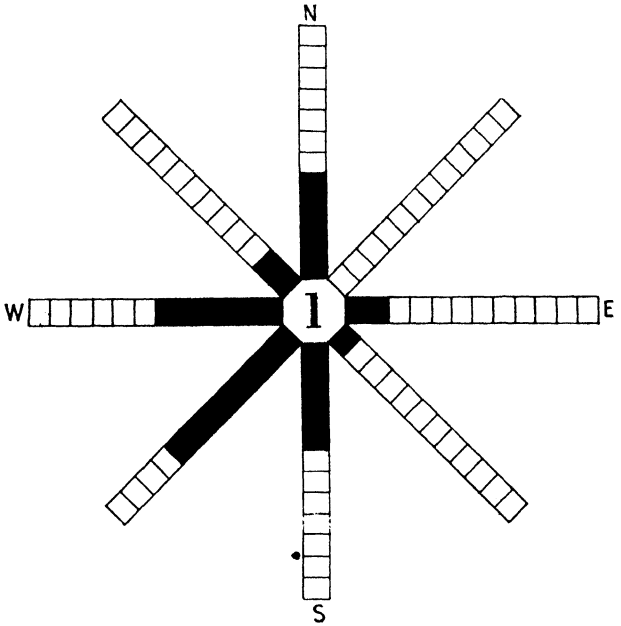


Fig. 69.—A polar chart.

Wind rose for South Farnborough November, 1950

(f) Clock Graphs (Polar Charts)

In these graphs quantities are represented on radii at proportionate distances from the centre of a circle. Values related to hours of the day, months of the year, etc., can be shown by this method. The representation of meteorological data is an obvious example: the change of temperature throughout the day, the amount of rainfall throughout the year, etc., could be shown by variable radii from a centre. If the ends of the radii be joined different patterns will emerge characteristic of different régimes.

Generally, however, this method is not to be recommended for most statistical records, since better means can usually be employed. The one exception is the wind rose, illustrated in fig. 69, where the radii represent direction: in this case there is no suitable alternative.

(g) Block Piles (Three-Dimensional Graphs)

This is an adaptation of the Sten de Geer volumetric treatment of population. The graphs consist of pictures of blocks, cylinders, spheres, etc., in which the volumes are proportionate to the quantities represented. In order to overcome the difficulty of appraisal for volumetric representations of this kind the geometrical solids may be split up into countable units of which the cube is the most favoured, hence the term 'block pile'.

Figs. 70 and 71 illustrate the method. The national income and national savings of the United Kingdom for the period 1938–48 is shown by two different methods. In fig. 70 a pyramid represents the national income with the proportion of national savings shown in black at the tip. In fig. 71 the more conventional block pile has been used to illustrate the statistics. The actual figures in millions of pounds sterling were as follows.

	National Income	Savings
1938	4,886	143
1946	8,712	678
1947	9,027	165
1948	9,592	6

THE UNITED KINGDOM

National Income (white) and National Savings (black) in Pounds Sterling 1938-1948

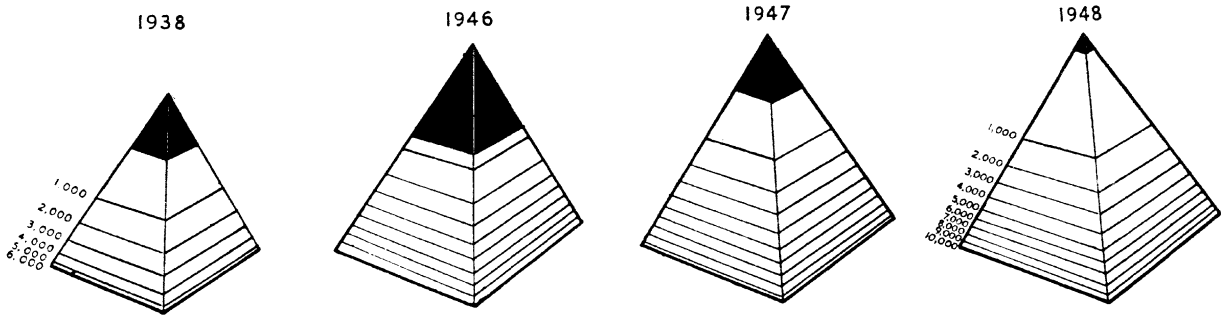


Fig. 70

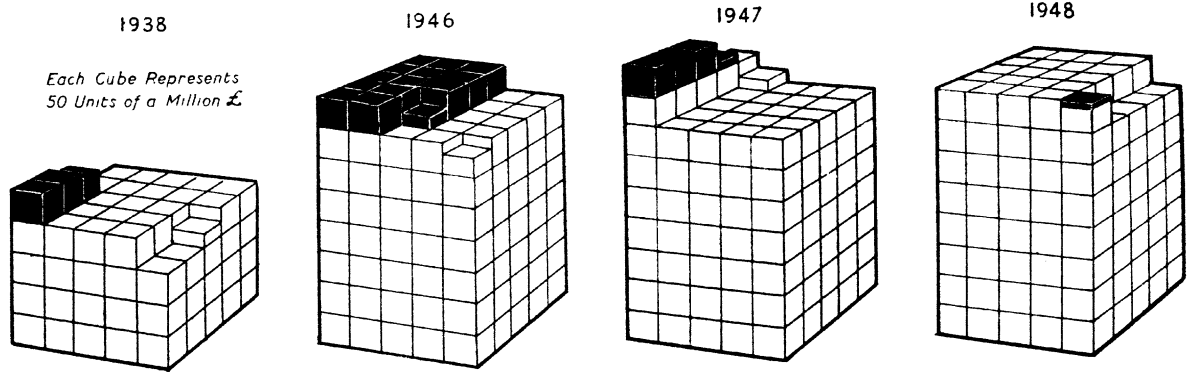


Fig. 71

Figs. 70, 71.—Examples of block piles.

29 Constructional Notes

Success in map and diagram construction can frequently prove to be a very elusive quality. Whilst some individuals seem to be born draughtsmen others never quite manage to achieve a finished-looking result. A small minority just cannot make any grade, but the greater number can achieve reasonable success if attention be paid to a few simple rules and points. A light touch, neatness, efforts to keep the drawing clean, elimination of over-elaborate designs are some essentials; whilst the drawing effort can be improved still more by the use of a variety of mechanical aids and adherence to standard styles, the more useful of which are dealt with *seriatim* below.

(a) Line Shading

Mechanical transfers on transparent and adhesive paper can be used if the work is intended for reproduction or display and merits the extra expense. These aids are known as Zip-a-tone transfers and, although of American manufacture, can be obtained in this country.

Normally, however, the geographer will be faced with constructing his own line shading. The essential quality to aim at will be neatness and uniformity, lines must be of equal thickness, strictly parallel, and with the spacing exact. This may be achieved by preliminary subdivision and the use of a ruling-pen and rolling parallel ruler. Alternatively, graph paper placed under the map on an illuminated glass-topped tracing desk may be used as a guide to the spacing of lines.

Whilst simple patterns of dots, rulings, and cross rulings can be repeatedly built up, it may be desirable to try and relate the number of lines per inch to the quantities being represented. The construction of proportional density lines may prove difficult when attempts are made to subdivide an inch into an awkward number. This can be overcome by a geometrical method, illustrated in fig. 72.

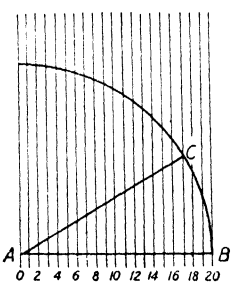


Fig. 72

An inch is subdivided into an equal number of parts, say 20, by a series of parallel ruled lines drawn perpendicularly to the base *A–B*. On *A–B* a quadrant is erected, radius 1 in. and centre *A*. The subdivisions are labelled 0–20. Now suppose it is desired to place 17 lines to the inch. Find the point where the parallel line labelled 17 cuts the quadrant, at *C*, and draw in radius *A–C*. This line is 1 in. in length and will clearly be subdivided into 17 equal parts. This gives the desired interval for spacing the lines.

In all forms of line shading an attempt should be made to grade from one shade to another. Mixtures of lines and cross-hybrid symbols and the like should not be used. In special cases pure white and pure black should also be avoided, since it is very difficult to shade into either.

(b) Colour Tinting

Smooth colour washes are not difficult to obtain if attention is paid to two or three small points. Clearly, before starting, an ample supply of thin colour wash should be mixed and made available to ensure a uniform shade. This should not be allowed to settle. A large brush with a fine point enables the wash to be put on quickly. Most important of all, the wash should be applied rapidly, working from the top of the paper to the bottom, but not allowing the bottom edge to dry at any point in the application. If the bottom corner is reached with too much colour wash still left, this may be removed with a dry brush. Each colour should be allowed to dry before applying the next in contact with it.

If shades of one colour are being used, a uniform gradation may be obtained by starting with the darkest colour and systematically adding uniform amounts of additional water to obtain lighter tones. Another alternative is to use a single light tint and then apply superimposed washes. For professional work it is possible to purchase poster paints in graduated tones.

It should be remembered that many people are to varying degrees colour-blind, and complex maps with but slightly different shades of colour may be difficult to interpret. In these cases a system of numbering or lettering to supplement the colour (as in some geological maps) is advisable. If different colours are used to express density they should be optically graded. This does not necessarily imply a spectrum order—yellows and reds frequently stand out more so than neighbouring colours.

(c) Dot Maps

The main difficulties in the construction of a dot map consist of obtaining dots of uniform size and, where necessary, of aligning them uniformly and neatly. The latter can usually be solved by placing the map over graph-paper resting on a tracing frame. Uniformity in the size of the dots may be achieved in the following ways:

(*a*) PENS. Special dotting pens, such as the Leroy or Uno pen, will give good results, but failing these a normal reservoir nib with a round flattened tip may be used. Quite good dotting pens can also be made from a drawn-out glass tube. Large dots, of course, should be based on circles drawn with spring-bow compasses, and subsequently filled in.

(*b*) PUNCHES. This is a very effective way of producing neat and presentable dot maps, either for display purposes or at an elementary level. Black, white, or coloured circles may be punched out of fairly stiff paper by means of a paper punch, different sizes being obtainable according to the need. The paper circles can then be fixed to the map by rubber solution (see below), or they can be cut from adhesive paper and stuck on directly. An alternative method is to punch holes out of the map itself and then mount on a black background. Either method can be very effective, but is clearly limited in application.

(*c*) DIES. If access to printer's type is possible, dies are usually easy to obtain in a variety of shapes and sizes. These can be mounted in wooden handles. Printer's ink will be necessary to obtain the best results, and it is advisable to construct a pad fed with this type of ink. The dies are then used much as one would use a rubber stamp.

(*d*) PINS. When suitable boarding or display walling is available some very effective dot maps can be built up by using pins headed in various colours. Both plastic and glass tops are available. This type of map construction is also useful at an elementary level for demonstrating how to build up a dot map.

(d) Cartographic Adhesives

One of the best adhesives for use in cartographic work is rubber solution. This is a liquid mixture of rubber and petrol which is applied to the surfaces to be joined. The petrol base evaporates on exposure to the air and the rubber solidifies. The surplus rubber may be gently rubbed off, and in performing this operation the paper is automatically cleaned. Being a completely dry process, there is no problem of paper shrinkage or expansion. There is also the additional advantage that the two surfaces which have been stuck together can, with care, be separated without damage, if desired.

Another useful cartographic aid is drafting tape. This is an adhesive tape which can be used for fixing tracing paper over a map, or for fixing down maps, drawings, etc. The tape only lightly adheres and can be removed after completion of the work. It is possible to use the tape several times before the adhesive quality disappears, and this probably accounts for it being known as Scotch tape amongst many draughtsmen.

(e) Lettering

This is one of the most important and at the same time can be one of the most difficult problems of cartography. We shall not in these notes be concerned with the more complex aspects of the problem, despite their fascination: it will be more appropriate to concentrate on some little-known or essential points to assist in improving what is usually the weakest part of any map construction. Unfortunately too many good maps are spoilt by poor lettering, and the geographer may frequently find his work being unconsciously judged on the basis of his ability in this sphere. Every effort, therefore, should be made to encourage good lettering. Complicated styles should be avoided, simple styles that give clear and legible results, are neat in appearance, and rapid in execution should be employed. The script type of writing makes an excellent basis.

Certain conventions in the use and placing of names have gradually been adopted by cartographers and the most important of these are as follows:

(*a*) Lettering should be in straight horizontal lines as far as possible and names should read to or from the described symbols or object.

(*b*) When (*a*) cannot be arranged, names should be placed on a curve, again reading to or from the place, but only in the manner shown in fig. 73. Only these four curves are employed by the professional cartographer.

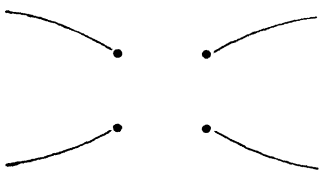


Fig. 73

(*c*) Names for features extending over a large distance or area may be placed on gently sweeping curves, but these curves should never undulate.

(*d*) Names consisting of two or more words should never be so widely separated as to cause doubt concerning their relationship, and, conversely, unrelated names should be clearly separated.

(*e*) Names of rivers should follow the course in a convenient position with the lettering on the northern side.

(*f*) Lower-case letters are usually employed for features which exist as a place or line—cities, rivers, peaks, etc., whilst capitals are used for features extending over large areas—countries, oceans, regions, mountains, etc.

In the actual production of the lettering, improved results will come if careful note is made of the following constructional hints:

(*a*) Avoid over-elaborate forms, keep the lettering neat, simple, uniform in size, and well formed.

(*b*) Letters must appear to be correctly spaced. This applies particularly to large letters, titles, etc. It is important to realize that the letters should *look* correctly spaced, although in fact the linear distance between them is not constant. This is because the eye actually judges area and not distance between the letters. It is well to note that some letters are self-spacing:

A O Q T V W X Y

whilst others require extra space on one side:

B D E F K L P J

and others require space on both sides:

H I M N U

(*c*) The rule for spacing between letters applies equally to spacing between words.

(*d*) Faint pencil guide-lines will assist in obtaining uniformity. Horizontal lines may be used for upper and lower case letters, whilst sloping lines will ensure uniformity in italics.

(*e*) Letters should be lightly pencilled in at first. Ink in later.

(*f*) For script-type letters use a stiff and broad-pointed nib and keep the angle of presentation to the paper constant. Variations in width will then be obtained automatically and consistently.

(*g*) Ink should only exist on the underside of the nib, and the nib should be kept clean when not in use.

Much assistance can be obtained by the geographer from the use of a stencil such as the standardgraph or Uno type, particularly where large capital letters are involved. Printed alphabets and printing alphabets can also be obtained: these are useful for building up large-lettered words neatly. A variety of other mechanical aids are available to the professional cartographer, but as they are not available to the geographer under normal circumstances, they have not been considered in this statement.

(f) Map Compilation

The professional cartographer engaged in the production of normal topographic maps, air maps, marine charts, etc., has a complex compilation procedure which depends on the availability of material, speed of production, method of reproduction, and the like. The geographer making his own maps does not need a complete knowledge of all these processes, for his own productions will be simpler and less detailed, probably illustrating some particular distributional pattern or a particular point. Despite the simpler approach, however, the principles behind the compilation remain the same and the geographer will do well to pay attention to the following points:

(*a*) Whenever possible, reductions from large-scale maps should be employed. Never enlarge unless forced to, since small errors will be magnified.

(*b*) If the map is to be reproduced, draw on a slightly larger scale than that intended and then photograph down to the desired scale: 3/2 and 2/1 is a normal exaggeration. This improves the result and reduces the irregularity of any lines.

(*c*) Work out the scale of the compilation, bearing in mind the area to be covered, size of the paper available for the final map, and whether a drawing on an enlarged scale for subsequent photo-reduction is desired.

(*d*) The map must be drawn on a framework. This should be the graticule of a projection appropriate to the work in hand. Most geographical work calls for equal-area (equivalent) projections rather than orthomorphic (conformal) projections. This point should be watched carefully. Most geographers in the past have merely traced off some existing map without regard to projection, with, in many cases, some unfortunate results.

(*e*) Compile the map on the basis of the graticule, squaring in and tracing off as necessary. Preliminary drafting should be done in pencil. No definite sequence can be laid down at this point as procedure will depend on the nature of the material. The aim should be to make the map *accurate*, *clear*, and *legible* and *adequate*. Avoid unnecessary data. Concentrate at this stage on the insertion of line work only.

(*f*) On completion of the line work, attention is paid to lettering. Using guidelines, outline the lettering in pencil, bearing in mind the various principles already noted above.

(*g*) The essentials of the map are now complete in draft form. The next step is to ink in. First remove superfluous graphite with a powder eraser (grate up a hard rubber) and dust off. Inking-in is done on a priority basis, since in overlapping work the most important work is left unbroken. The sequence is usually:

(i) Names of countries, mountains, political divisions (these are difficult to place owing to spacing).
(ii) City names.
(iii) River names.
(iv) The symbol content—roads, railways, towns, etc.
(v) Parallels, meridians, and borders.

(*h*) With the main body of the map complete attention can now be paid to the accessory data and the geographer must decide what the map needs from the following list:

(i) Title.
(ii) Graphic scale and/or representative fraction.
(iii) Key to conventional signs, altitude tints, isopleth, and choropleth tints, etc.
(iv) List of any abbreviations.
(v) Projection data.
(vi) North point (desirable if graticule is not shown on large scales).

In maps with sea room, necessary accessory data may be positioned inside the borders. Otherwise it must go outside. An effort should be made to obtain a well-balanced result.

Careful attention to these main rules and principles of procedure will produce a result which is geographically functional and also cartographically fault-free.

30 Sources of Statistical Information

Statistical data on which to base exercises in map and cartogram construction will naturally be related to the course in progress. Clearly, the teacher must be responsible for the selection of the data that the class is going to express in map form. It would therefore be inappropriate to present any selection of statistical information in this account. On the other hand, some indication of useful sources may be helpful to many teachers.

Any local survey or local study that the teacher attempts with the class will be much improved by cartographic and diagrammatic illustrations. Local statistical data can usually be obtained from the Town Clerk or the Medical Officer of Health. County statistics may similarly prove of interest if obtained from the local county offices.

The source for population data will be the census reports, and these should be obtainable in any good reference library. The school library itself will probably contain suitable reference works, such as the *Statesman's Year Book*, *Whitaker's Almanack*, *Chambers's Encyclopaedia*, etc., and these can frequently be of great value in providing useful and suitable information. For advanced work the teacher will find the publications of the Central Statistical Office (London) of potential value. This office collects information from the statistics divisions of Government Departments and issues an Annual Abstract of Statistics together with a Monthly Digest. The variety of information contained in these two publications is fascinating, ranging over climate, population, vital statistics, social and economic conditions, education, production, trade, transport, and finance.

At the international level, of course, the United Nations Organization publishes a wide array of statistical information. Thus, there should be little difficulty in obtaining statistics to illustrate the greater part of the normal work undertaken by the geography teacher. Recent and up-to-date information will not only assist the text-book interpretation of any problem, but will also provide a ready means of stimulating interest among the pupils and students.