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C. A. WOOD, M.A., F.R.G.S., F.G.S.,

1st Prizeman at Edinburgh University; Supervisor of Student Teachers under the Middlesex County Council; Late Principal of Hounslow P.T. Centre; Sometime Lecturer at Leith Technical College; Author of *A Modern Geography*, *A Physical and Economic Geography*, etc.

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PREFACE.

The recent changes introduced into the teaching of Geography have created a demand for a new kind of text-book, and it is to meet this demand that the following pages have been written.

Special attention has been paid to the geological structure of the British Isles with reference to its scenic effect and its influence on national activity.

An attempt has therefore been made in the following pages to preserve a due sense of *proportion*, and to concentrate the reader's attention on the most fundamental features.

It was with this object in view that maps illustrative of the most salient facts have been inserted, and the drawing of these maps in preference to those which are more detailed is strongly recommended, although a good atlas should invariably be used while studying the text.

If the student has leisure, he should read newspapers, magazines, and especially the description of explorers of their own travels, and he will thus convert his study of geography into a real delight, and will be able to deal intelligently with current national problems requiring a sound geographical knowledge.

Chas A Wood

A Physical & Economic Geography.

MATHEMATICAL, ASTRONOMICAL, AND PHYSICAL GEOGRAPHY.

In addition to the sun, moon, stars, planets, meteorites, and comets, which can easily be seen by the ordinary observer of the heavens, there are many stars, planets, satellites, asteroids, comets, and meteorites, that are only visible by means of the telescope, and it is only by the intelligent use of this instrument that astronomers have been enabled to acquire a scientific knowledge of the heavenly bodies.

These heavenly bodies may be classified as follows:—

I. Self-Luminous Bodies.

(*a*) **The Fixed Stars,** to which group the Sun and such well-known constellations as "The Great Bear" belong.

(*b*) **Comets,** which consist of meteoric "heads" and gaseous "tails." A few of the comets have repeated their visits to the Solar System several times.

(*c*) **Meteorites,** which are solid particles, and glow in consequence of friction, caused by rushing through the earth's atmosphere, or by colliding with one another. "Shooting Stars," so-called, belong to this group.

II. Non-Luminous Bodies.

(*d*) **Planets,** which shine by reflecting the sun's rays, and wander through different constellations, thus changing their relative positions. The Earth is one of the planets.

(*e*) **Satellites,** which also shine by reflection. The moon is an example.

(*f*) **Asteroids,** which hold their course between the orbits of Mars and Jupiter, and are supposed to be fragments of a broken planet.

Although the sun is 93 millions of miles from the earth, it is nearer to us than any of the other stars, the nearest of which

Alpha Centauri—is 250,000 times farther from us than the sun. The planets and satellites, however, are much nearer to us than the sun, round which they revolve in elliptical orbits.

The Solar System.

The Solar System consists of:—

(*a*) The Sun, which is the centre of the system.

(*b*) Eight planets, *viz.*, Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.

(*c*) The Satellites of the various planets.

(*d*) The Asteroids, the largest of which is very much smaller than the moon.

(*e*) Many comets. Some comets, after revolving round the sun, never return to the solar system.

(*f*) Meteorites.

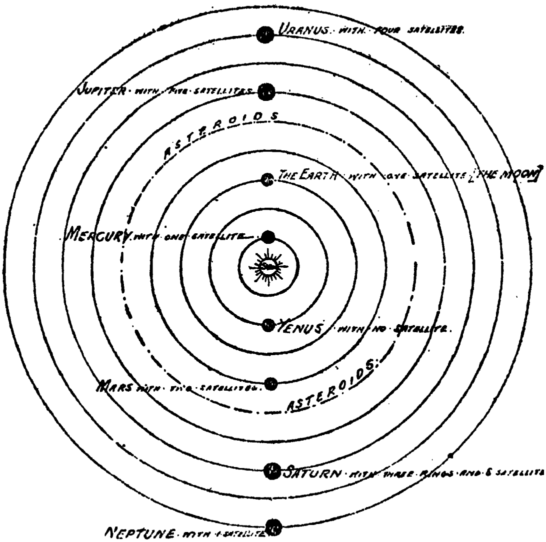


Fig. 1.—The Solar System.
Relative Order of the Planets.

The Sun, Planets, and Satellites are the principal members of the Solar System, and the above diagram represents their relative *order* from the centre.

Mercury is the nearest planet to the centre of the Solar System, its distance from the sun being 36 millions of miles. Adopting this distance as a standard, the distances of the planets may be approximately represented as follows:—

Inferior Planets	Mercury	1.
	Venus	2.
The Earth		3.
Superior Planets	Mars	4.
	Jupiter	13.
	Saturn	25.
	Uranus	50.
	Neptune	78.

These relative distances may also be represented graphically by lines as shown in the diagram below —

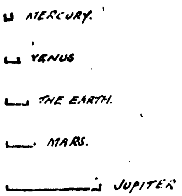


FIG. 2.—RELATIVE DISTANCES OF PLANETS FROM THE SUN.

As the lengths of the orbits of the planets vary with their distance from the sun, the time taken by the several planets to complete a revolution varies considerably; from 88 days in the case of Mercury, to 165 years in that of Neptune. Venus takes 225 days, the earth 365 days, Mars nearly 2 years, Jupiter 12 years, Saturn 29 years, and Uranus 84 years.

The *sizes* of the planets do not, however, correspond with their distances from the sun. Jupiter is the largest, with a diameter of 86,500 miles, which is about eleven times greater than that of the Earth. The sun has a diameter equal to ten times that of Jupiter. The diameter of Mercury is 3,000 miles and in terms of this distance, the diameters of the rest of the planets may be represented as on the next page.

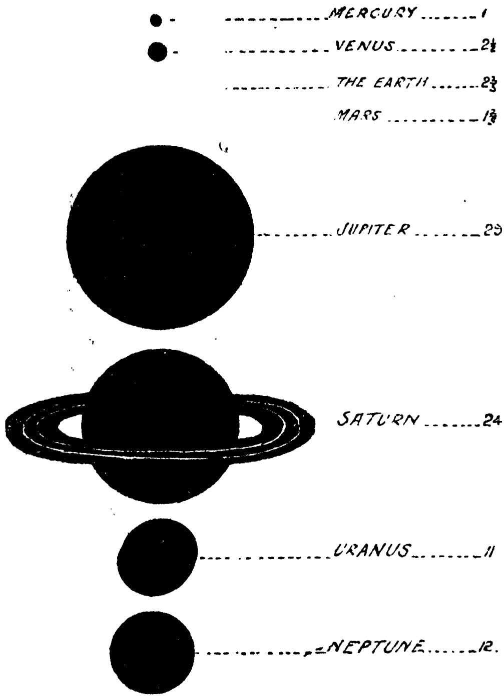


FIG. 3.—RELATIVE SIZES OF THE PLANETS.

The Earth.

Shape.—The Earth, though a little flattened at the poles, and of uneven surface, is approximately spherical.

PROOFS OF THE ROTUNDITY OF THE EARTH.

(1) The funnel is the last part of a receding steamer that is visible to an observer on the sea-shore.

(3) If three posts are placed in a straight line at a considerable distance from one another, and are so arranged that they are of an equal height above a "level" surface, such as that of a canal, the middle post appears higher than the others when viewed in a straight line, owing to the convexity of the Earth's surface.

For example, if the interval between each post is one mile, the apparent increase in height of the middle post is eight

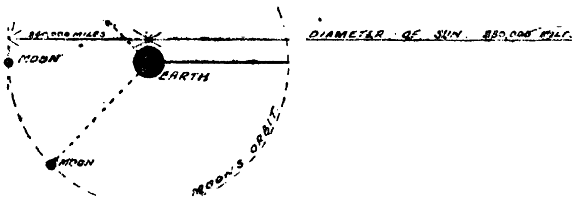


FIG. 4.
DIAMETER OF SUN'S DISC COMPARED WITH MOON'S DISTANCE FROM THE EARTH.

inches. From this amount of curvature the circumference of the Earth may readily be estimated.

SEA-LEVEL.

The surface of the ocean partakes of this curvature, the "sea-level" at a given place being the average height of the tide at that place. The sea-level on the British Ordinance Survey Maps refers to the average height of the tide at Liverpool. It should be remembered that the sea-level varies considerably not only in distant parts of the world, but even along the British coast.

(3) If a man is on the highest eminence in a neighbourhood, his view is bounded by a circular horizon, the horizon being the line where the sky appears to touch the earth. The higher the eminence, the farther away the horizon appears to be removed, the view consequently being more extensive. The distance to the horizon depends upon the observer's height, and may be found as follows :—

$$\text{Distance to horizon} = \sqrt{\text{earth's diameter} \times \text{observer's height.}}$$

If observer is 6-feet.

$$\text{Distance} = \sqrt{8{,}000 \text{ miles} \times 6\text{-feet}} = \sqrt{8{,}000 \times \tfrac{1}{880} \text{ miles.}}$$

$$= \sqrt{9} = 3 \text{ miles roughly.}$$

The level surface connecting all the points of the circle of the horizon is called the horizontal plane.

(4) The Earth's shadow, as seen upon the moon during a lunar eclipse, is always round.

PROOFS THAT THE EARTH IS FLATTENED AT THE POLES.

(1) The height of the North Pole Star, as determined by the angle enclosed by two imaginary lines drawn from the observer's position to the North Pole Star and horizon respectively (see diagram 5), is equal to the observer's latitude. For example, the North Pole Star when viewed from London has an altitude of $51\frac{1}{2}°$, and this corresponds to the *latitude* of that place. At Naples, the latitude of which is 40° N., the star's altitude is 40° N. At Bombay it is 20°, and at the equator 0°.

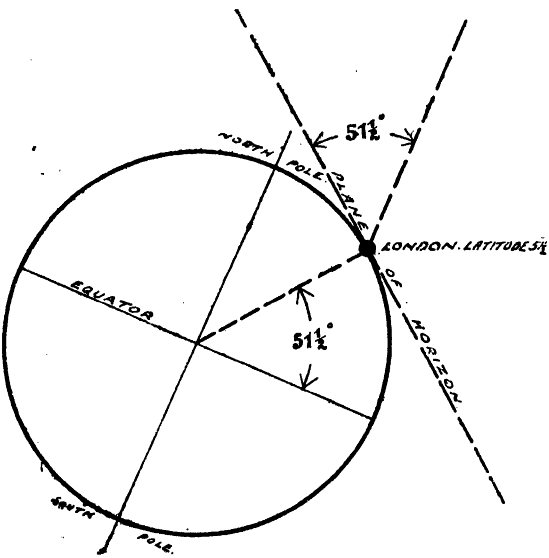


FIG. 5.—LATITUDE DETERMINES ALTITUDE OF NORTH POLE STAR.

As we travel towards the equator, the North Pole Star appears to be lower in the sky, and it is evident that if the Earth were strictly spherical, the amount of decrease in altitude would be in proportion to the number of miles travelled north or south. It is found, however, that at the equator it is necessary to travel 68·69 miles in a northerly direction to cause a difference of one degree in the altitude of the North Pole Star, whereas near London a difference of one degree requires 69·1 miles. The Earth therefore cannot be spherical, but is an oblate spheroid, *i.e.*, it is flattened at the Poles. A traveller consequently finds that the length of a degree of latitude is slightly increased as he journeys towards the Poles.

(2) The force of gravity, as determined by the pull on a spring balance, is slightly less at the equator than it is at places farther north or south. This is in consequence of the centre of the Earth being farther from the equator, than it is from the surface of the Earth at places situated some distance to the north or south of that line.

Size.—The circumference of the earth is about 25,000 miles. Its equatorial diameter—7,926 miles—is 26 miles longer than its polar diameter.

Its area is nearly 200 million square miles, and of these about three-fourths consist of water.

Motions.—The Earth has a rotary and also a revolving motion. It rotates *daily* from west to east on its axis, during its *annual* revolution round the sun. Its rotation causes the alternation of day and night, whilst its revolution produces the seasons.

Proofs of the Earth's Rotation.

(1) A stone allowed to fall from the top of a high tower falls slightly towards the east, because the top of the tower is moving more rapidly to the east than its base, in consequence of the earth's rotation. The stone that falls from the tower retains the same velocity as the top of the tower in consequence of its inertia.

(2) The sun and the stars appear to move from east to west, and to complete a circular path round the heavens in the course of 24 hours.

(3) A heavy pendulum hanging from the centre of the ceiling of a lofty building is not affected by the earth's rotation, and continues to swing in one direction. The floor of the building, rotating with the earth, makes a complete circle in 24 hours,* and the walls change their relative position with regard to the

* More correctly, 24 hours × cosec. of latitude. '24 hours' is correct only at the Poles.

direction of the swing of the pendulum. This principle has been used by Foucoult in his pendulum and gyroscope experiments.

PROOFS OF THE EARTH'S REVOLUTION.

(1) The sun does not always appear to be in the same constellation or group of stars during successive months of the year. It *seems to travel completely round the sky in a period of twelve months. This annual path of the sun is called the ecliptic.* If this path be noted throughout the year, it will be found to pass

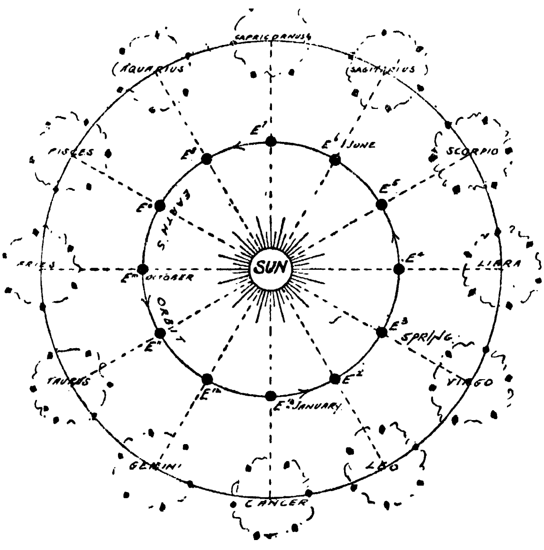


FIG. 6.—SIGNS OF THE ZODIAC.

through certain constellations which form a continuous belt round the heavens. This belt is called the *zodiac* and the twelve constellations therein are named the signs of the zodiac. The reason why people generally know so little of the various constellations through which the sun passes at different times of the year, is that they are not visible during the day unless a telescope is employed. For further explanation see Fig. 6.

Capricornus, Aquarius, etc., represent the background of the sky. E^1, E^2, etc., represent the Earth in its orbit, at different times of the year.

E^1 is the earth's position in January.

S is the sun.

When the earth is at E^1, an observer projects the sun by means of a straight line to the constellation Capricornus, and *the sun is thus seen in that constellation. When the earth is at E^2, the sun is projected to Aquarius, and so on. It is therefore* evident that the sun appears to travel completely round the sky in the course of a year.

(2) A slight change in the position of the stars is noticeable at different times of the year, owing to the earth's being in different parts of its orbit.

(3) A knowledge of the relative masses of the sun and the earth, and of the universality of the law of gravitation, is evidence that the Earth revolves round the sun, and not vice versa.

Latitude and Longitude.

The **Earth,** though a little flattened at the poles and of uneven surface, is approximately spherical, and imaginary lines have been drawn around it; one series from north to south, and another series from east to west, in order to determine the exact positions of places.

The most important of these lines is the **Equator,** which drawn round the earth, midway between the poles.

It passes through Ecuador, Columbia, and Brazil in South America; French Congo, Congo State, Uganda, and British East Africa in Africa; and Sumatra, Borneo, Celebes, and Gilolo in the East Indies.

The second most important line is one which is drawn at right angles to the equator and which passes through Greenwich and the Poles. It is called the **first meridian of longitude.**

It crosses France, Spain, Algeria, the Sahara, and the Gold Coast Colony.

The lines between the Poles and Parallel to the equator are named **parallels of latitude,** while the lines drawn *through* the Poles are called **meridians of longitude.** The meridians divide the equator into 360 parts or degrees, and since the equator has a length of nearly 25,000 miles, the length of a degree, at the equator, is approximately 69¼ miles (25,000÷360).

As we proceed from the equator to the Pole, the length of a degree of longitude becomes less, the length of a degree of longitude in any particular latitude being found by multiplying the cosine of that latitude by $69\frac{1}{2}$.

EXAMPLE.—To find the length of a degree of longitude in latitude 30°:

$$\text{Cos. } 30^\circ = \sqrt{3} \quad \text{length} \quad \sqrt{3} \quad \tfrac{1}{2} = 59 \text{ miles.}$$

As this calculation requires advanced mathematics, the following table is given to enable the student to find the length of a degree of longitude at varying latitudes.

The length of a degree of longitude at	0°	latitude is, roughly,	$69\frac{1}{2}$	miles.
,, ,, ,, ,, ,, ,,	10°	,, ,, ,,	68	,,
,, ,, ,, ,, ,, ,,	20°	,, ,, ,,	65	,,
,, ,, ,, ,, ,, ,,	30°	,, ,, ,,	$59\frac{3}{4}$	,,
,, ,, ,, ,, ,, ,,	40°	,, ,, ,,	53	,,
,, ,, ,, ,, ,, ,,	50°	,, ,, ,,	$44\frac{1}{3}$	,,
,, ,, ,, ,, ,, ,,	60°	,, ,, ,,	$34\frac{1}{2}$	,,
,, ,, ,, ,, ,, ,,	70°	,, ,, ,,	$23\frac{3}{5}$	,,
,, ,, ,, ,, ,, ,,	80°	,, ,, ,,	12	,,
,, ,, ,, ,, ,, ,,	90°	,, ,, ,,	0	,,

From the above table the distance between places in the same latitude may easily be calculated, provided that their longitudes are known.

EXAMPLE.—**London** (5′ W.) is in the same latitude as **Bristol** (2° 35′ W.), namely 51° 3′ N.L. The difference in longitude is $2^\circ 35' - 5' = 2^\circ 30'$. Now the length of a degree in latitude 51° 3′ is about $44\frac{1}{3}$ miles, and therefore the distance between London and Bristol is $44\frac{1}{3} \times 2\frac{1}{2} = 110\frac{5}{6}$ miles.

The above table does not, of course, apply to places that are *not* in the same latitude.

As nearly all the important towns in the world are situated between 40° S.L. and 60° N.L., a list is given below of places situated in the same latitude between these degrees.

PLACES APPROXIMATELY IN THE SAME LATITUDE.

60° N.L.	50° N.L.	40° N.L.
Okhotsk.	Irkutsk.	Pekin.
Tobolsk.	Saratov.	Kashgar.
St. Petersburg.	Warsaw.	Bokhara.
Helsingfors.	Cracow.	Erzerum.
Stockholm.	Prague.	Naples.
Upsala.	Amiens.	Madrid.
Bergen.	Winnipeg.	New York.
Mt. St. Elias.	Victoria (Br. Clmb.).	Salt Lake City.

20° N.L.	20° S.L.	40° S.L.
Hanoi.	Charters Towers.	Bass Strait.
Cuttack.	St. Louis.	Valdivia.
Bombay.	Antananarivo.	Wanganui.
Suakin.	Beira.	
Dongola.	Buluwayo.	
Timbuktu.	Victoria (Brazil).	
Mexico.	Iquique.	
Honolulu.	Suva.	

The **Arctic and Antarctic Circles** are 23½° from the North and South Pole respectively. There are no towns within the Antarctic Circle, but within the Arctic Circle there are a few trading stations, of which *Fort Yukon* in Alaska, *Christianshaab* in Greenland, *Tromso* and *Hammerfest* in Norway, and *Verkhoyansk* in Siberia, are the best known.

Places between 23½° N.L. (Tropic of Cancer) and 23½° S.L. (Tropic of Capricorn) are within the tropics.

The length of a degree of latitude is practically invariable, namely, 69½ miles, and provided that we know the latitude of two places *on the same meridian* we may readily ascertain the distance between these places.

EXAMPLE.—**Berwick-on-Tweed** and **Birmingham** are on the same meridian, but the latitude of the former is 55° 47′ N., while that of the latter is 52° 28′ N., the difference in latitude is, therefore, 3° 19′, and consequently the distance between the two places is $3\frac{19}{60} \times 69\frac{1}{2}$ which gives 230½ miles.

PLACES ON THE SAME MERIDIAN.

30° E.L.	90° E.L.	135° E.L.
St. Petersburg.	Tomsk.	Khaborovsk.
Kiev.	Lhasa.	Vladivostok.
Constantinople.	Punakha.	Kioto.
Alexandria.	Decca.	Gladstone Gold-field.
Cairo.		
Dongola.		
Ujiji.		
Salisbury.		
Pietermaritzburg.		
75° W.L.	**120° W.L.**	**180°.**
Ottawa.	Vancouver.	Suva.
Montreal.	San Francisco.	
Albany.		
New York.		
Philadelphia.		
Washington.		

VARIATION IN TIME.

The diurnal rotation of the earth determines time, it being mid-day at all places on the meridian that is immediately opposite the sun. When it is mid-day at *Greenwich*, it is also mid-day at all places on the same meridian as Greenwich, *e.g.*, *Havre*, in France; *Castellon*, in Spain; *Mostaghen*, in Algeria; *Twat*, in the Sahara; and *Acra*, in the Gold Coast Colony.

When it is mid-day at *Greenwich*, it must be *after* mid-day at places east of Greenwich, and *before* mid-day at places west of Greenwich, since the earth rotates from west to east.

The earth rotates on its own axis once in twenty-four hours, *i.e.*, it rotates through 360° in twenty-four hours, or 15° in one hour, and therefore when comparing the time at any given place with Greenwich time, we add one hour for every 15° east, and subtract one hour for every 15° west.

EXAMPLE.—The longitude of **New York** is 76° W., and therefore when it is noon at Greenwich, it is $76 \div 15 = 5\frac{1}{15}$ hours *before noon* at New York, that is, 6.56 a.m.

Calcutta is in longitude 88° E., and therefore when it is noon at Greenwich, it is $88 \div 15 = 5\frac{13}{15}$ hours *after noon* at Calcutta, that is, 5.52 p.m.

To obtain local time of any place in England, add four minutes to Greenwich time for each degree of longitude that the place is east of Greenwich, but subtract if west of Greenwich.

GREAT AND SMALL CIRCLES.

All the meridians are *great circles* because their planes pass through the centre of the earth. The parallels of latitude, with the exception of the equator, are *small circles* as their planes do not pass through the centre of the earth.

ANTIPODAL POINTS.

The antipodes of any place is the point diametrically opposite on the other side of the earth. If we know the latitude and longitude of the place, we may determine the antipodal point in the following manner. Take the same latitude as the place, unless it be on the equator, and transfer it to the *opposite* hemisphere, north or south as the case may be. Now take the longitude, and subtract from 180°, again transferring it to the opposite hemisphere, east or west according to position. The point will thus have been determined. An example will make this clear. Calcutta is 22° 30′ *N.*, 88° 30′ *E.* Its antipodes is 22° 30′ *S.*, 91° 30′ *W.*

DAY AND NIGHT.

Since the earth is a dark body, and receives its light from the sun, it is obvious that only the half that is turned towards that luminary is illuminated, the other half being in darkness. Now the earth makes one rotation in 24 hours, and if the earth's axis were perpendicular to the plane of its orbit, all places would have twelve hours light and twelve hours darkness. In other words, days and nights would be equal in length all over the world, and there would be no seasons. This is apparent from a study of the following diagram.

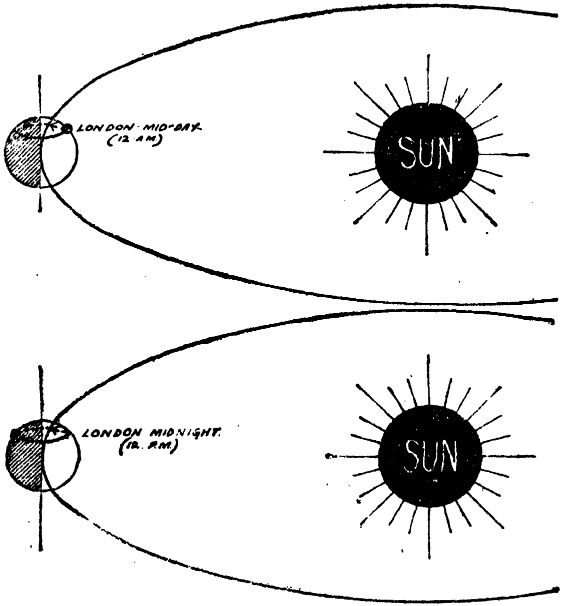


FIG. 7.—DAY AND NIGHT.

The earth's axis, however, is not perpendicular to the plane of its orbit, but is inclined at an angle of $23\frac{1}{2}^\circ$ from the perpendicular. This has a great effect on the lengths of days and nights in various parts of the world, as it causes portions of the earth's surface to receive much less heat from the sun at one time of the year than at another. This may be readily understood if we draw an ellipse to represent the earth's orbit, a line to represent the earth's axis inclined at an angle of 23½° to the ecliptic, and imagine the equator at right angles to the earth's axis.

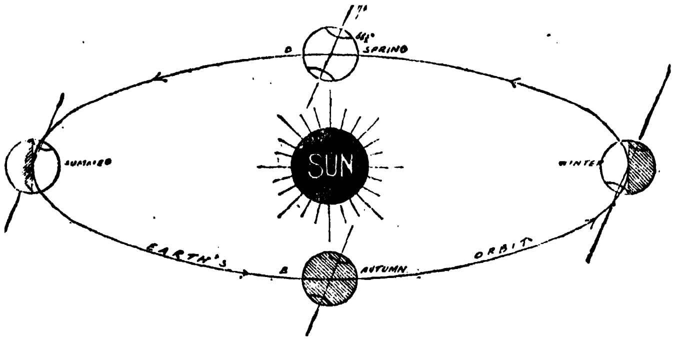


FIG. 8.—THE SEASONS.

Take a town situated at 66½ N.L., and notice how much light and how much darkness it would receive during one rotation in spring, summer, autumn, and winter respectively.

In *spring* (March 21st), the earth's axis is not pointing either towards or away from the sun, and thus there would be twelve hours light and twelve hours darkness. March 21st is called the vernal equinox.

In *summer* (June 21st), the northern portion of the earth's axis is turned towards the sun, and it would receive more light than darkness, and the climate would be warmer in consequence. It will also be observed from the diagram, that all places within the Arctic Circle, when the earth is in this position, are illuminated for twenty-four hours, thus accounting for the mid-night sun, while places in the Antarctic Circle are in darkness for the same length of time. June 21st is termed the summer solstice.

In winter, six months later (December 21st), when the earth has moved to C, the southern regions receive more light, and are consequently warmer, than the north. December 21st is the winter solstice.

At B, on September 23rd, the northern portion of the earth's axis is not directed towards the sun more than the southern portion, and therefore all places receive twelve hours light and twelve hours darkness during one rotation of the earth's axis. September 23rd is therefore the *autumnal* equinox.

At the time of the equinoxes the sun is vertically overhead at noon to observers at all places on the equator, *e.g.*, Quito. At such places, at noon, no shadow would be cast by the sun if a stick were placed in an upright position.

At the time of the winter solstice—December 21st—the sun is overhead at all places on the Tropic of Capricorn, and therefore

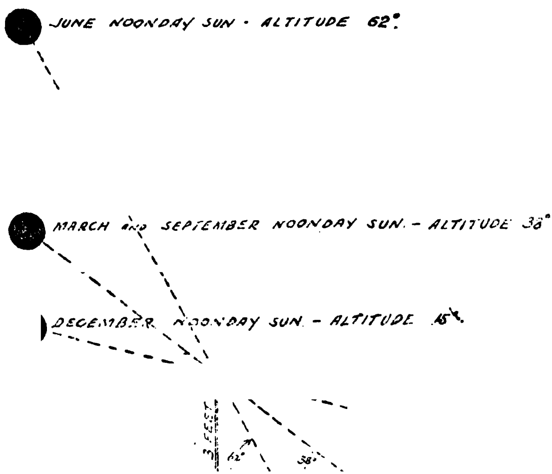


FIG. 9.—VARIATION IN THE SUN'S ALTITUDE.
AB = Length of Shadow in June = 1½ feet.
AC = " " " March and September = 3¾ feet.
AD = " " " December = 11 feet.

at all places *south* of 23½° S.L., the sun is seen higher in the sky on that date than at any other period of the year.

On June 21st—the summer solstice—the sun is immediately above the Tropic of Cancer, *e.g.*, Havana, and is therefore seen in its highest position on that date by observers in the more northern latitudes.

In England, for example, the sun's altitude is greatest at that time, and the student can easily find this out by actual observation. The sun's position should be noted in March, June, September, and December, and such a diagram as the following should be drawn. It is evident that when the sun's altitude is greatest, it will make its greatest arc in the sky, *that is, it will rise farther to the east and set farther to the west, than at any other period.*

A graph *might also* be made of the sun's altitude at noon during successive months of the year. Such a graph would indicate that the sun appeared to reach the Tropic of Cancer in June, to cross the equator in September, to reach the Tropic of Capricorn in December, and to cross the equator again in March. The similar altitudes observed in March and September synchronise with the crossing of the equator by the sun in those months.

It follows from the double crossing of the equator by the sun in a year, that the sun is twice vertically overhead at all places between 23½° N.L. and 23½° S.L., that is, at all places within the tropics in a maximum period of six months.

North and south of the Tropics the sun is *never* seen vertically overhead.

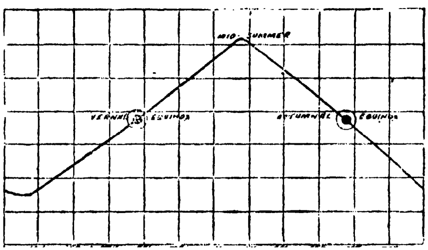


Fig. 10.—Variation in Sun's Altitude (London, place of observation).
Note that in March and September—the Equinoxes—the Sun has the same altitude, *viz.*, 38°.
In June the Sun is highest, being vertical over Cancer.
In Dec. „ lowest, „ „ „ Capricorn.

Shadows.—As the noonday sun in our latitude is highest in June, it is obvious that a shadow cast by a yard stick placed vertically, will be shortest in that month, and the following results should be verified by actual observation.

Length of yard stick shadow in June is 1½ feet.
" " " " March and Sept. is 3¾ feet.
" " " " December 11 feet.

From the length of the sun's shadow, not only may the *altitude of the sun be readily ascertained, but also the latitude of the place of observation, provided that the time of year is known.*

Length of Day.—Since the sun rises higher in the sky in summer than in winter, the arc described in the sky is greater in summer, and the length of day is also greater. In London the length of a day in midsummer is about twice the length of a corresponding day in mid-winter; sixteen hours, as compared with eight. At the equinoxes the length of daylight is twelve hours. At the equator there are about twelve hours of daylight per day throughout the year. Within the Arctic and Antarctic Circles the duration of daylight varies from 24 hours in mid-summer, to 0 in mid-winter. The student should draw a graph of the duration of light throughout the year from his own observations, or from the following data taken from Whitaker's Almanac.

	The Sun Rises.	Sets.		The Sun Rises.	Sets.
	H.M.	H.M.		H.M.	H.M.
January 1st ..	8. 8	3.58	July 1 .	3.48	8.18
February 1 ..	7.42	4.46	August 1 .	4.23	7.49
March 1 ..	6.49	5.36	September 1 .	5.13	6.48
April 1 ..	5.39	6.29	October 1 .	6. 0	7.40
May 1 ..	4.35	7.19	November 1.	6.54	4.34
June 1 ..	3.51	8. 4	December 1.	7.45	3.53

The Seasons.—The earth's revolution round the sun, together with its rotation on an axis inclined at an angle of 23½°, is the cause of the seasons. It has already been explained that the length of day and night varies throughout the year. When our day is longer than the night, it is obvious that the amount of heat received is increased, and this accounts for the summer season. But it must also be remembered that the length of time that the sun is shining is not the only cause of summer. *The direction of the sun's rays* must also be taken into consideration. In summer the sun's altitude is greatest, and its rays are consequently more direct, or more nearly perpendicular, than at any other time of the year. This results in a greater number of heat rays falling on a given area, a fact which is illustrated by the following diagram:—

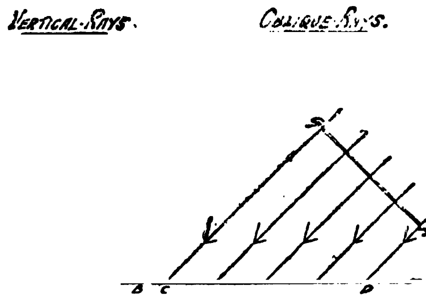


FIG. 11.—OBLIQUITY AND TEMPERATURE.
EF=GH.
CD is longer than AB.

VERTICAL AND OBLIQUE RAYS.

EF is a pencil of vertical rays falling on a portion of the earth's surface. GH is a pencil of the same number of rays falling obliquely. The area CD, covered by the more oblique rays is much greater than that covered by EF, and since the same number of rays falls on this *greater* area, the average amount of heat imparted must be *less*. This directness of the sun's rays in summer more than counterbalances the fact that we are actually farther from the sun in that season of the year than in winter.

Ferrel's Law.—"If a body moves in any direction on the earth's surface, there is a deflecting force arising from the earth's rotation which tends to deflect it to the *right* in the northern hemisphere, but to the *left* in the southern hemisphere." This is known as Ferrel's Law.

In accordance with this law, a north wind in the northern hemisphere tends to become north-east, *e.g.*, the Trade Winds, while a south wind becomes south-west, and the general circulation of the atmosphere in the northern regions is therefore *clock-wise.*

In the southern hemisphere a south wind tends to become south-east, *e.g.*, the Trade Winds, and a north wind tends to become north-west, thus causing a *contra-clockwise* circulation in the southern hemisphere. Similarly, a clock-wise circulation of the waters of the oceans in the northern hemisphere is noticeable

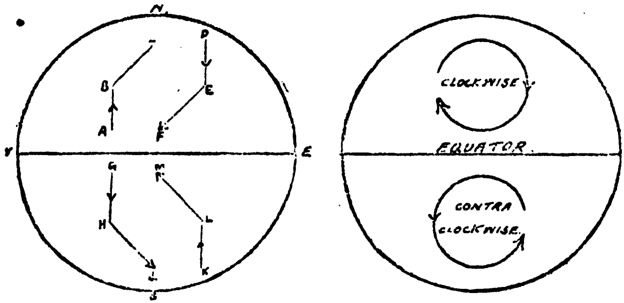


FIG. 12.—FERREL'S LAW.

AB	tends to become	BC, *i.e.*, South	wind	becomes	South-west	wind.
DE	"	"	EF, *i.e.*, North	"	"	North-east wind.
GH	"	"	HJ, *i.e.*, North	"	"	North-west wind.
KL	"	"	LM, *i.e.*, South	"	"	South-east wind.

and a contra-clockwise circulation in the southern hemisphere is also manifest, giving rise to the Sargasso Seas.

The long rivers of the northern hemisphere, *e.g.*, in Siberia, are noticed to flow with greater force against their right banks, cutting them back considerably. The diagram above illustrates the principle of Ferrel's Law.

The Cardinal Points.—To obtain the cardinal points, mark the

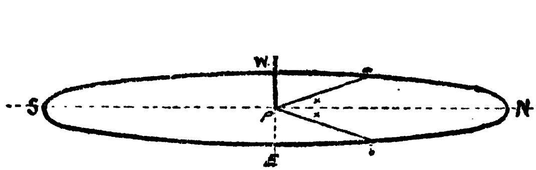


FIG. 13.—THE CARDINAL POINTS.
Pa is the Morning Shadow. *Pb* is the Afternoon Shadow

sun's shadow at about 11 a.m., as cast by a stick placed vertically

Draw the circle of which this shadow is a radius, and note the shadow of equal length cast in the afternoon. Draw the direction of this shadow, and bisect the angle between the directions of the two shadows already observed. This will give a true north and south line. Mark the N and S points, and then fix points 90° from them. That point to the left (when facing the south) will be the east, and the one to the right will be the west.

The cardinal points may also be fixed at night by means of the North Pole Star. This star can easily be found by using the pointers of the constellation known as the Plough or the Great Bear. These pointers are so called because they point *nearly* to the Pole Star. The Pole Star, *Polaris*, does not coincide *exactly* with true north, but is due north at midnight in the month of October.

The Plough.—If this group of stars be observed for a few hours, it will be noticed to be revolving round the North Pole Star, taking up such positions as are shown below:

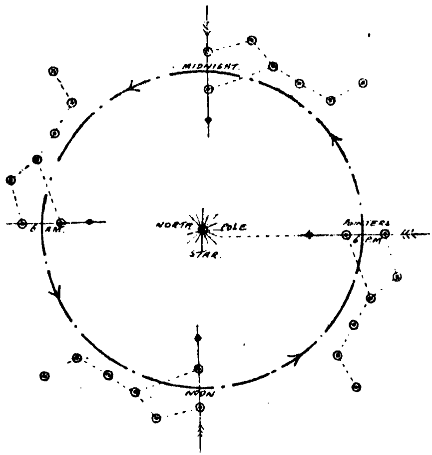


FIG. 14.—THE PLOUGH AND THE NORTH POLE STAR.

The Rising and Setting of Stars.—Other constellations may be observed to make similar revolutions round the North Pole Star. If a star that is far removed from the North Pole Star be thus observed, the circle that it appears to make round that star will be of considerable size. It may be so large that a portion of the circle dips below the horizon, and such a star would therefore be seen to *rise in the east*, and *set in the west*. The following diagram will explain such rising and setting.

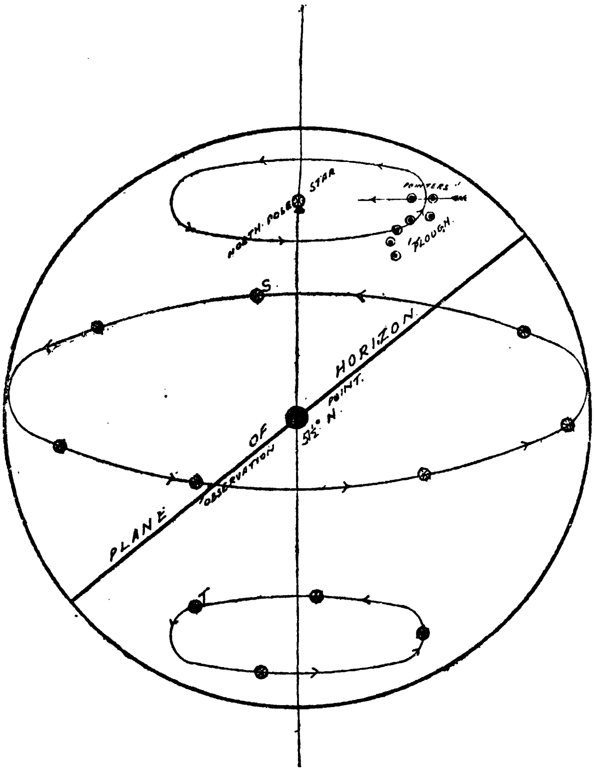


FIG. 15.—RISING AND SETTING STARS.
The "Plough" never sets. "S" rises and sets. "T" never rises.

We have therefore some stars, such as the North Pole Star, which *never set*, and others which both *rise and set*. But there are some stars which *never rise* in our latitudes. This is obvious when we remember that we only see the northern half of the heavens, the Earth itself preventing us from seeing the southern half. We should have to visit some country in the southern hemisphere, *e.g.*, New Zealand, in order to make a complete survey of the sky.

Thus, as our point of observation varies, the position of a star seems to vary also. At the equator, for example, the North Pole Star appears on the horizon. It is, therefore, possible to determine the *latitude* of any place from an observation of the stars.

Altitude and Azimuth.—The position of a star is fixed when its altitude and azimuth are known. The *altitude* is the height of the star above the horizon. The *azimuth* is its distance east or west of south.

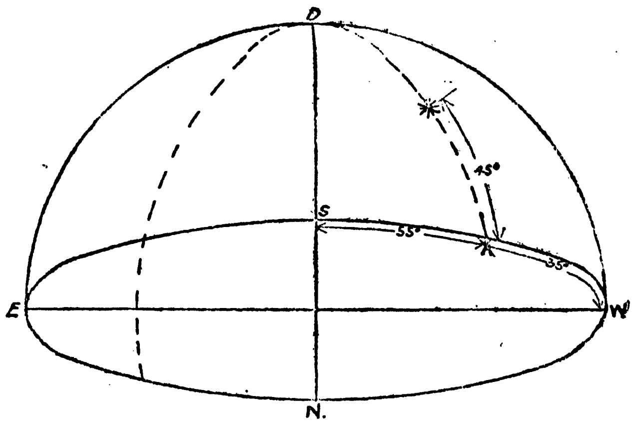


FIG. 16.—ALTITUDE 45°—AZIMUTH 55°W.

Let SENW represent the horizon, S being the south.

Let EDW be the dome of the sky.

The number of degrees from the horizon to the star is estimated on the vertical circle on which it is situated (45° in the above diagram). This is the altitude.

Then the number of degrees from the foot of the vertical circle to the south is estimated, and its position east or west is noticed (55° W. in diagram). This is the azimuth.

The Star's position in the above diagram is therefore Altitude 45°, Azimuth 55° W.

Sundial.—To obtain true solar time as distinct from "clock" time, a sundial is employed. The shadow thrown by the style

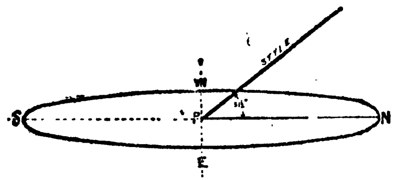


FIG. 17.—SUN DIAL.
PN is the shadow at noon.

being opposite the sun, indicates its position. The style must not, however, be vertical to the dial-plate, but must be inclined at an angle equal to the latitude of the place. In London, for example, it must be inclined at an angle of 51½°, in order that it may be parallel to the earth's axis.

If the circular plate of the dial is placed at right angles to the style (when the style has been fixed at an angle of 51½° to the plane of the horizon), then the divisions on the plate may be drawn equal to one another, *i.e.*, 30° for each hour. If the plate, however, is horizontal, the divisions on it are unequal.

Equation of Time.—As the sun appears to travel faster through the sky at certain times of the year, the sundial does not always agree with the clock. The clock is sometimes *before*, sometimes *after*, the sun. It is, therefore, often necessary to subtract a few minutes from, or to add a few minutes (never more than 17) to, sundial time to obtain clock time, and the amount added or subtracted is called the "Equation of Time." Four times in a year the clock and sun are together. In 1907 these times were April 17th, June 15th, September 2nd, and December 26th.

The Phases of the Moon.—The moon shines by reflecting the sun's rays, and only one half is illuminated at any given time. It depends, therefore, how much of this illuminated portion is turned to us as to its appearance or phase. If the whole of the illuminated surface is turned to us, it is full moon; if half, it is half moon; and so on.

It must not be thought that the moon's phases are caused by the earth's shadow. The earth's shadow can only fall on the

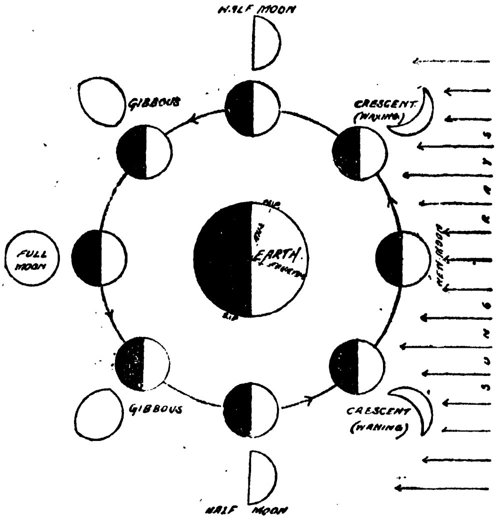


FIG. 18.—MOON'S PHASES.

moon when the latter is "full," and the phenomenon is then known as a total or partial eclipse of the moon.

Lunar Eclipses.—A lunar eclipse does not occur every month,

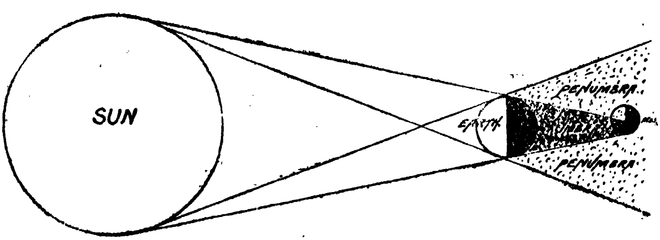


FIG. 19.—LUNAR ECLIPSE.
The upper part of the moon is in the Penumbra.
The lower " " " Umbra (deepest shadow).

owing to the plane of the moon's orbit not coinciding with the plane of the earth's orbit.

Solar Eclipse.—Sometimes the moon passes directly between the earth and the sun, totally or partially obscuring the sun's disc from an observer on the earth. Such an effect is called a solar eclipse.

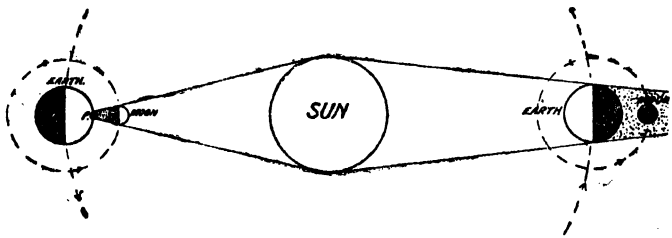


FIG. 20.—ECLIPSES.

SOLAR ECLIPSE. LUNAR ECLIPSE (Total).

To an observer at P the Sun is invisible.

The Mariner's Compass.—The mariner's compass consists of a magnet free to move in a horizontal plane, which moves a compass card attached to it. The fleur-de-lis of the card which indicates the North is above the North Pole of the magnet.

The Earth's Magnetism.—The magnet, acted upon by the earth's magnetism, "sets" in a definite direction, but it must not be supposed that it points to the true north. It does not coincide, for example, with the direction of the north and south line as obtained by means of the North Pole Star or the noonday sun. It makes an angle, at the present time, in this country of 16° 16′ W. with this line. This angle is called the magnetic declination, and allowance must be made for this when finding the cardinal points with a compass.

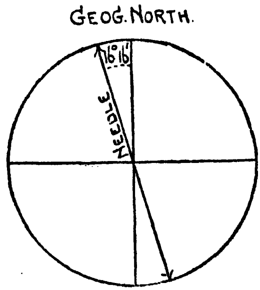


FIG. 21.
MAGNETIC DECLINATION AT LONDON 16° 16′.
Needle moves in a horizontal plane.

To find the true north, allow the needle to set itself and then fix a point 16° 16′ *east* of the north pole of the magnet. Draw a line from this point to the centre of the magnet. This line will be in a true north and south direction.

The amount of declination varies in different parts of the world, but there are many places that have the same declination, and the lines connecting such places are called *isogonic* lines. These lines have roughly a north and south direction.

Magnetic Dip.—A needle free to move perpendicularly makes an angle with the horizontal in this country, of 67°, and this angle is called the dip. Lines connecting places having the same dip are called *isoclinic* lines. They have, roughly, an east and west direction. There are two places in the world where the needle dips vertically, namely, Felix Boothia in Canada, and Antarctica. Amundsen has found that the former position, known as the north magnetic pole, is not constant. The south magnetic pole in Antarctica has now been located by actual experiment. There is considerable variation in the direction of the earth's magnetism from year to year, as indicated by magnetic needles in our own country, and also in other parts of the world.

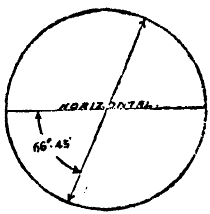


FIG. 22.
MAGNETIC DIP AT LONDON 66° 45'.
Needle moves in a vertical plane.

Gravitation.—The Law of Gravitation, as expressed by Sir Isaac Newton, is as follows:—"Every particle of matter in the Universe attracts every other particle with a force whose direction is that of the line joining the two, and whose magnitude is directly as the product of their masses, and inversely as the square of their distance from each other."

From this law it appears that the force of gravitation between two bodies, *e.g.*, the moon and the earth, varies directly according to their masses and inversely according to the square of their distance from each other.

Let F represent the force of gravity.
" M " " mass of earth.
" m " " " moon.
" d " " distance between earth and moon.

Then it follows that $F = \frac{M \times m}{d^2}$.

By the force of gravitation the various members of the solar system are upheld in space and are kept in their relative position.

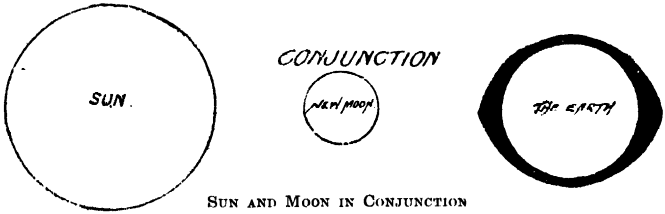
The force of gravity exerted by the Earth on any object may be considered to be acting from a point situated at the *centre* of the earth. Thus the earth tends to draw any object which is on its surface towards its centre. Now because the earth's Polar diameter is less than its Equatorial diameter, any object situated near the Poles is nearer to the centre of the earth than a similar object situated near the Equator. Consequently an object near the Poles would be attracted with greater force, or would weigh more, than a similar object which might be nearer the Equator.

The weight of an object varies according to its position, since the weight of a body is the measurement of the Earth's attraction for that body. Weight thus differs from mass. The latter is invariable and is independent of position. Suppose a gun, for example, has a weight of ten pounds at the base of a mountain, its weight at the summit would be *less*. This could be proved, provided we weighed it by means of a spring balance. Its *mass*, or quantity of matter would be the same.

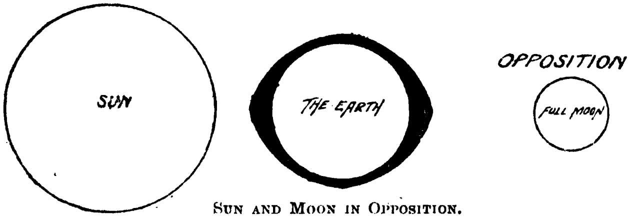
Tides.—A most interesting example of gravitation is afforded by the influence of the moon and sun in the production of tides. The moon, being nearer to the earth, exerts a greater influence on the tides than the sun does. For simplicity, imagine the oceans to form a watery envelope round the earth. During the period of one rotation of the earth, that is in 24 hours, all portions of this watery envelope would be successively brought to face the moon, and would be pulled away from the land when in such a position. This heaping up of the waters is called *high tide*. But while the water *facing* the moon is being raised up, that on the side of the earth *turned away* from the moon is being left behind, and is thus heaped up also. This is so because the moon's attraction for the water farthest removed is less than for the land farthest removed, especially as the land is rigid, and the attraction for it is consequently felt at the centre of the earth, which centre is obviously much nearer the moon than the water farthest removed.

It follows, therefore, that there are two high tides in about 24 hours at any given place.

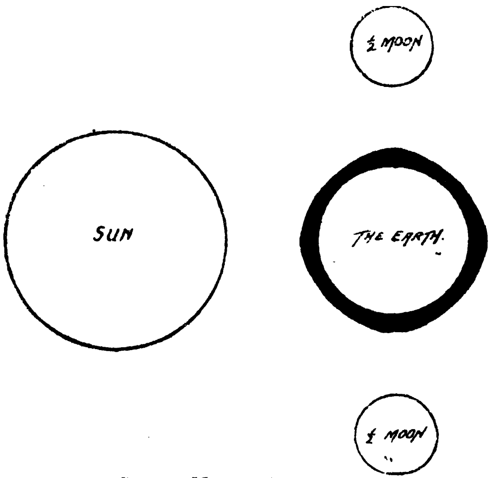
The sun exerts an influence similar to that of the moon, but in a less degree, on the waters of the earth.



SUN AND MOON IN CONJUNCTION



SUN AND MOON IN OPPOSITION.
FIG 23.—SPRING TIDES (Fortnightly).



SUN AND MOON IN QUADRATURE.
FIG. 24.—NEAP TIDES (Fortnightly).

When the sun, earth, and moon are in the same straight line, *i.e.*, when the moon is new or full, the attraction on the waters of the Earth is greatest, and the resulting tides—the Spring tides—are the highest (see diagram).

At the period of half moon when the sun's attraction is exerted in a direction at right angles to that of the moon, the *tides* are lowest, and are called neap *tides* in consequence (see diagram).

The chief cause of the tides is, therefore, the attraction of the sun and moon on the centre of the earth, as compared with their attraction on the water which is nearest, and also on that which is farthest away.

The attraction thus considered is called the "differential attraction" of the sun and moon.

The following diagram illustrates the importance of this differential attraction.

$$\text{The sun's attraction for A} = \frac{\text{Sun's mass}}{(\text{Distance from A})^2} = \frac{332{,}000}{(92{,}564{,}000)^2}.$$

$$\text{B} = \frac{\cdots}{(\text{Distance from B})^2} \quad \frac{332{,}000}{(92{,}572{,}000)^2}.$$

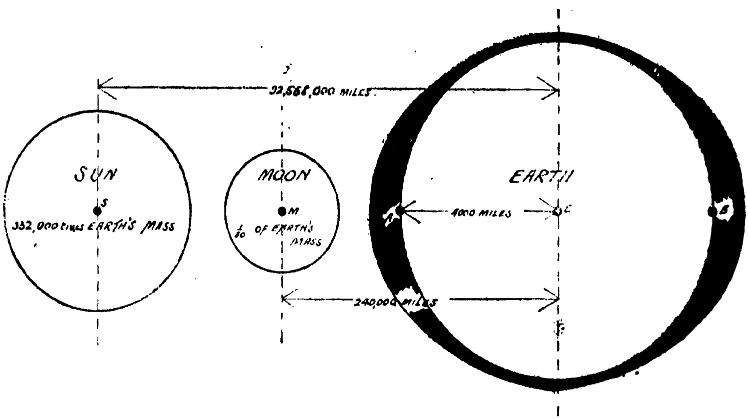


FIG. 25.—TIDES.

$$\therefore \text{The sun's differential attraction} = \frac{332{,}000}{(92{,}564{,}000)^2} \quad \frac{332{,}000}{(92{,}572{,}000)^2}$$

$$= \text{M, say.}$$

$$\text{Moon's attraction for A} = \frac{\text{Moon's mass}}{(\text{Distance from A})^2} = \frac{\frac{1}{80}}{(236{,}000)^2}.$$

$$\text{B} = \frac{\text{Moon's mass}}{(\text{Distance from B})^2} \quad \frac{\frac{1}{80}}{(244{,}000)^2}$$

$$\text{Moon's differential attraction} = \frac{\frac{1}{80}}{(236{,}000)^2} - \frac{\frac{1}{80}}{(244{,}000)^2}.$$
$$= \text{N, say.}$$

If N and M be compared, it will be found that N : M as $2\frac{1}{2}$: 1, that is, the attraction of the moon is $2\frac{1}{2}$ times greater than that of the sun.

High Water.—If the oceans formed a watery envelope completely covering the earth's surface, all places in the same longitude would have high tide at the same hour. The irregular configuration of the continents, and of the masses of land generally, interferes with the passage of the tidal wave, and, therefore, the times of high tides for ports which are approximately in the same longitude vary a great deal, as is evident from such a table as the following:—

High Water, January 1st, 1908.

London	11.29 a.m.	11.59 p.m.
Liverpool	8.58 ,,	9.24 ,,
Bristol	4.31 ,,	5. 0 ,,
Hull	3.41 ,,	4.10 ,,
Greenock	9.40 ,,	10. 9 ,,
Leith	Midnight.	12.20 ,,
Dublin	8.15 a.m.	9. 4 ,,

It will be noticed from the above table that successive high tides at the same port are separated by an interval, not of 12 hours, which we might expect, but of nearly $12\frac{1}{2}$ hours. This is due to the lunar day being 24 hours *$50\frac{1}{2}$ minutes* in length.

MAPS.

Conventional Signs. — The student should obtain Ordnance Survey maps (6-inch and 1-inch scale) of his own district and notice the various conventional signs, as shown in Fig. 26.

Scales.—A scale of 6 inches to 1 mile means that a distance of 6 inches on the map represents a distance of 1 mile of level country, that is, 6 inches on the map represents 63,360 inches on the ground. This relation is shown by the following ratio:—

6 : 63,360 or 1 : 10,560 or $\frac{1}{10560}$.

Similarly the scale on a 1-inch map is represented by the fraction $\frac{1}{63360}$, there being 63,360 inches in a mile.

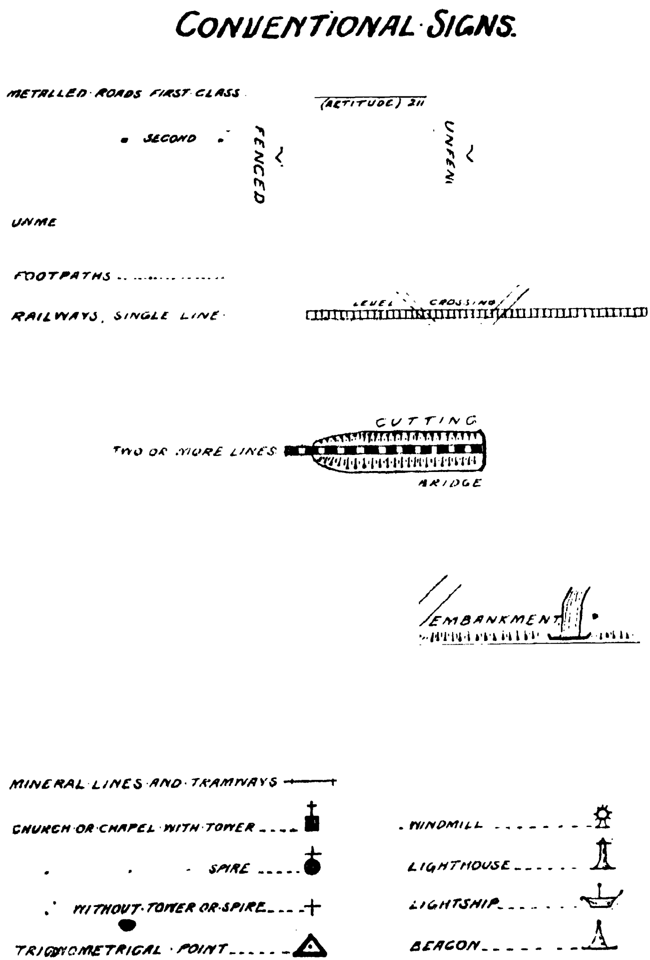

CONVENTIONAL SIGNS.
METALLED ROADS FIRST CLASS
(ALTITUDE) 211
SECOND
FENCED
UNFEN
UNME
FOOTPATHS
RAILWAYS, SINGLE LINE
LEVEL CROSSING
CUTTING
TWO OR MORE LINES
BRIDGE
EMBANKMENT
MINERAL LINES AND TRAMWAYS
CHURCH OR CHAPEL WITH TOWER
SPIRE
WITHOUT TOWER OR SPIRE
TRIGONOMETRICAL POINT
WINDMILL
LIGHTHOUSE
LIGHTSHIP
BEACON

Fig. 26.

Representation of Heights.—Heights are represented on a map by contours, hachures, figures, difference in colour, or by a combination of two or more of these.

Contours.—Contour lines are drawn to show the outline of a country at various altitudes. They connect places on the map which are at the same height above sea-level. The vertical

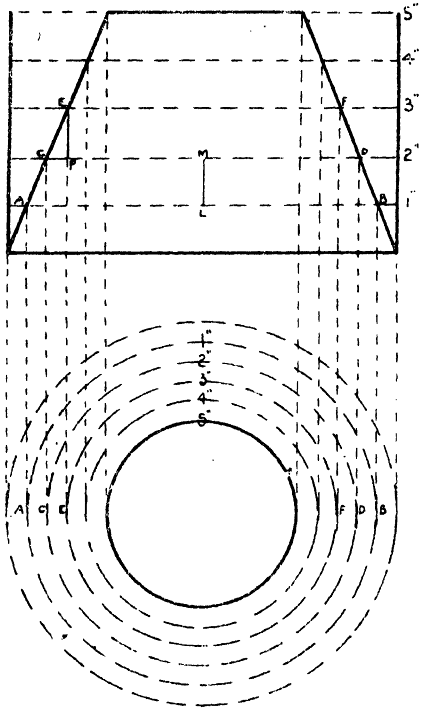


FIG. 27.—FLOWER POT AND ITS CONTOUR.
CP=Horizontal equivalent. LM=Vertical interval=1".

distance between the contours is called the vertical interval (V.I.). The horizontal distance between the contours receives the name of the horizontal equivalent (H.E.). To understand this, take an ordinary flower-pot, five inches in height, and invert it in a vessel containing water one inch in depth. Draw a line where the surface of the water touches the side of the flower-pot. This is the first contour line, its vertical interval being one inch. Now pour water into the vessel until depths of two, three, four, and five inches are successively obtained, marking the outline of the surface of the water where it touches the pot in each case. We thus get five contour lines, which we may transfer to paper in the form of a plan as indicated in the diagram. CP is the horizontal equivalent.

We notice that the higher contours fall within the lower ones, the highest contour being in the centre. This is because the flower-pot, when inverted, narrows uniformly towards the top. Most hills are somewhat conical in shape. Consequently the higher contours of such hills fall within the lower ones when represented on a map, though the contours are usually of a somewhat irregular shape.

If the contours are irregular in outline as in the accompanying diagram, the *concave* contours, looking from B to A, indicate a

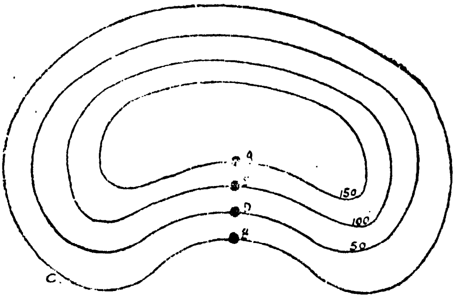


FIG. 28.—IRREGULAR CONTOUR.

valley down which a stream may flow. B would be visible from A in such a district. The *convex* contour lines, from C to A, show that this portion of the hill is *not* of the nature of a valley leading to the top. There would be no stream flowing from A to C, and C would not be visible from A on account of the intervening convex side of the hill.

The closer the contours come together the steeper the gradient, *e.g.*, EA is slightly steeper than DE.

IRREGULAR CONTOURS.

To prove that C is not visible from A, draw a straight line from

C to A, and mark the points on this line where it meets the 50 contour line and the 100 contour line by the letters C′ and C″ respectively. Now erect perpendiculars C′L, C″M, and AN of heights corresponding to the scale, that is $C'L = \frac{1}{4}$ inch, $C''M = \frac{1}{2}$ inch, and $AN = \frac{3}{4}$ inch. [Scale 200 feet to 1 inch.] Draw the straight line CN and notice that it cuts the perpendicular line C′L at H. This proves that H is a convex portion of the hill, and prevents C from being visible to an observer at A.

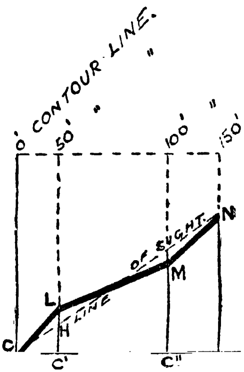


FIG. 29.
SECTION TO PROVE THAT C IS INVISIBLE FROM A.

Now apply these principles to a map of some definite portion of the earth's surface, *e.g.*, the contour map of Fujiyama.

It will be observed that the contours near the summit of this mountain are very close together, indicating that the slope of the mountain is exceedingly steep near the top. Two rivers flow southwards down valleys which are indicated by *concave* contour lines.

The mountain rises so abruptly that it is found advisable to take 1,000 feet as the Vertical Elevation. If a much less vertical elevation were adopted, the contours would almost touch one another, unless the scale of the map were considerably enlarged.

Cross Section of the Contour Map in the direction of AB. Such a section is obtained by drawing perpendiculars from every point where the contours cut AB to meet the horizontal lines where the distance between any two lines represents 1,000 feet.

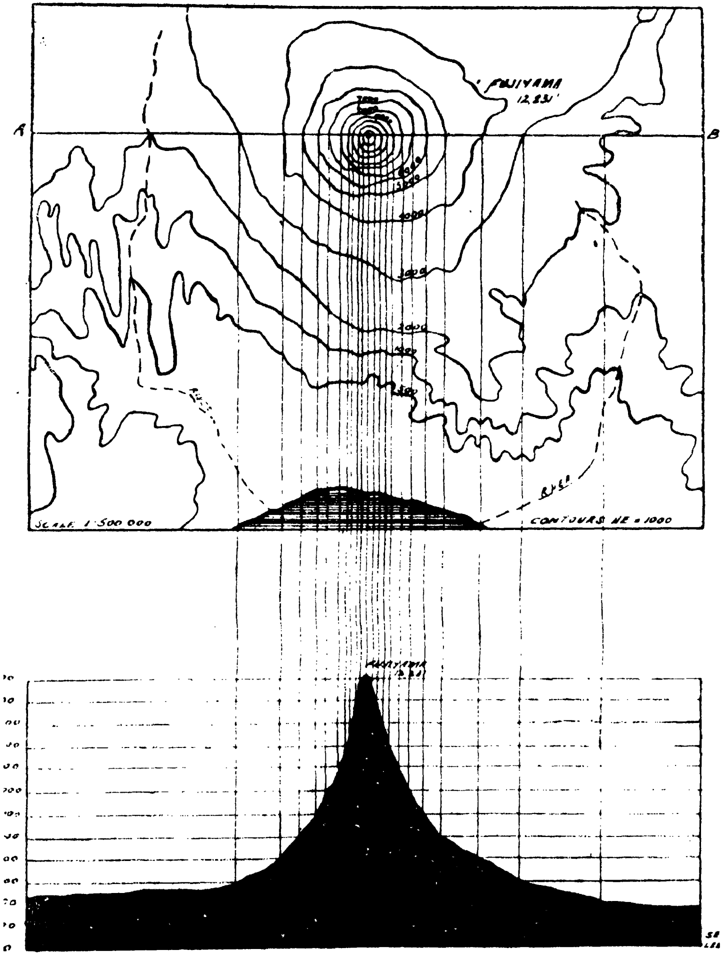


FIG. 30.
CONTOUR MAP OF FUJIYAMA.

A very different contour map, as compared with Fujiyama, is obtained when we represent any portion of the London District, *e.g.*, Richmond. No portion of the map is more than 200 feet in height, and even on a one-inch map, with contours for every 50 feet of elevation, the lines are few and wide apart.

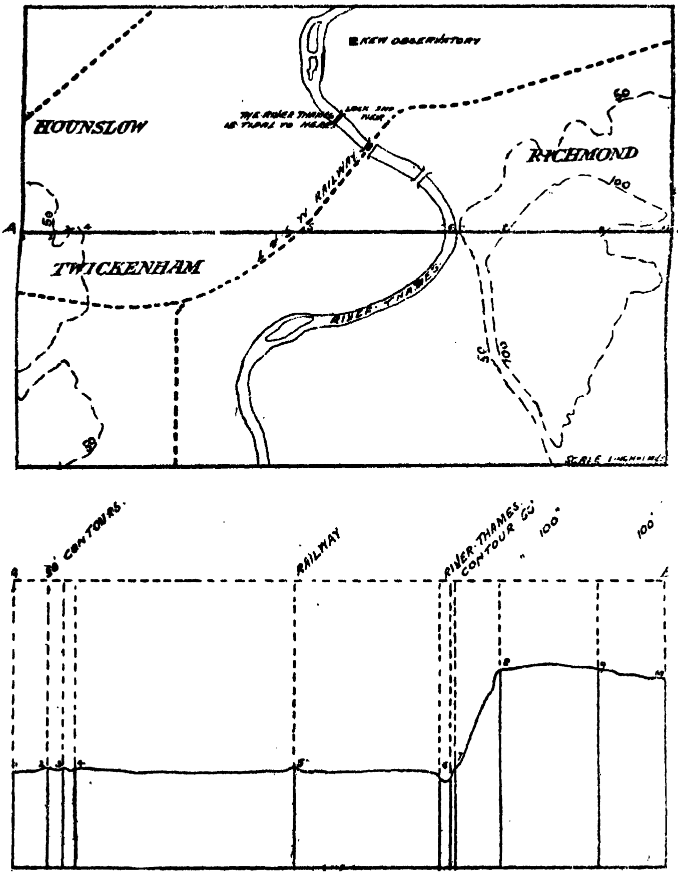


FIG. 31.
CONTOUR MAP AND CROSS-SECTION OF RICHMOND.

The accompanying map of a hilly portion of the West Riding of Yorkshire should be compared with the adjoining map of the

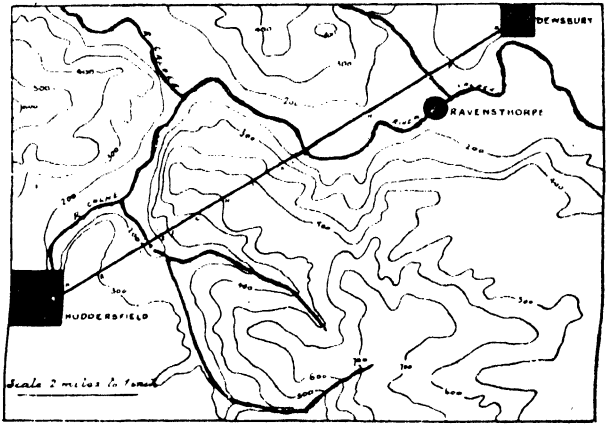


FIG. 32.—PLAN OF PORTION OF PENNINES.

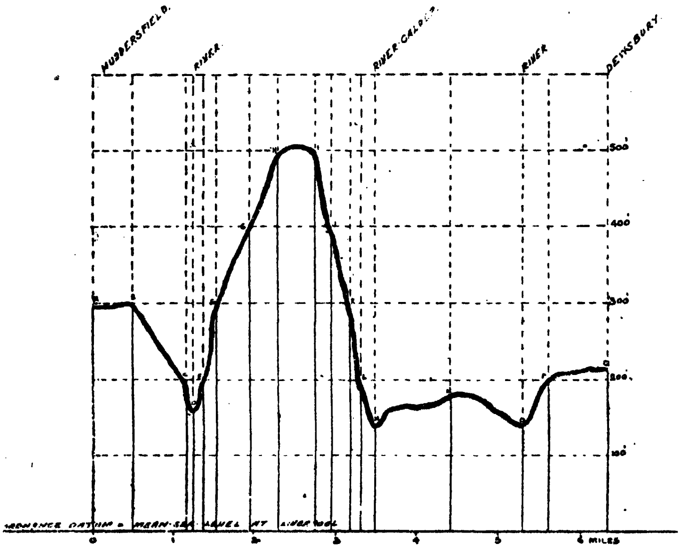


FIG. 33.—SECTION OF PORTION OF PENNINES.

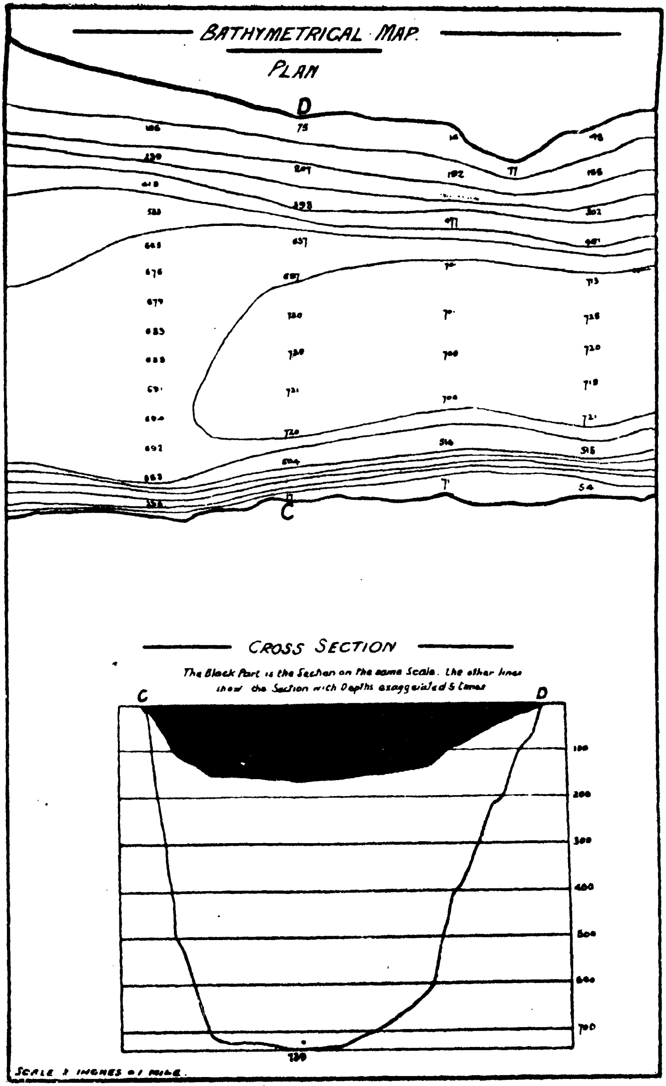


FIG. 34.—BATHYMETRICAL MAP OF LOCH NESS.

London District. On this map there is no point below the 100 feet contour line, not even the River Calder. The tributaries of the Calder flow down valleys indicated by the *concave* portions of the contour lines.

To obtain the cross section of AB it must be remembered that lines are drawn at right angles to AB.

Hachures on a map are short lines drawn down the slopes of a country to indicate its relief. If the gradient varies, the steeper portions are represented by hachures that are *closer together*. The hachures in the map of Fujiyama, for example, are closer

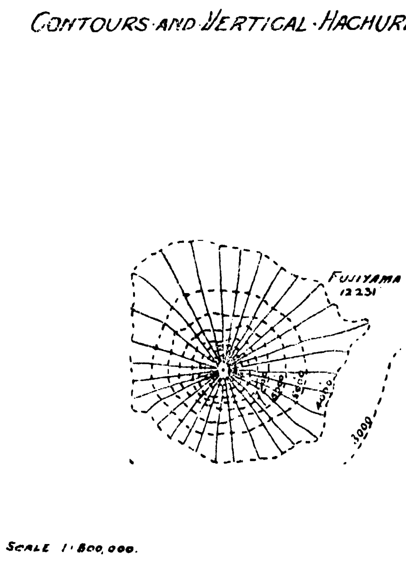


FIG. 35.—HACHURE MAP OF FUJIYAMA.

together towards the summit, indicating that the mountain becomes steeper towards the top. Hachures on an ordnance survey map are usually drawn much closer than those on the map given, but it has been thought advisable in this book to exaggerate the principle which underlies all hachure drawing.

A Bathymetrical Map is one that represents depths of water. Fig. 32 is a bathymetrical map—3 inches to 1 mile—of a portion of Loch Ness in Scotland. The depths are given in feet, and the contours have been drawn with a vertical interval of 100 feet. A glance at the contours reveals the fact that the water near the southern shore of the lake at C is much deeper than the water at a corresponding distance from the northern shore at D. A cross section of the lake has been made in the direction CD, and is given below the plan. A much better idea of the bed of the lake is obtained by exaggerating the depths, as is evident from the unshaded portion of the section.

SURVEYS.

Surveys are made in order to obtain a map or record of the relative positions of the chief physical features of any portion of a country.

The following three methods are most commonly adopted in surveying :—

1. Triangulation.
2. Traverses.
3. Astronomy.

Triangulation.—This method is often adopted for an extensive survey. A base line AB is carefully selected on as level a piece of ground as possible, A and B being prominent objects some miles apart, and visible one from the other. The distance between A and B is carefully measured with a steel tape, corrections being made for temperature (if not 62°F.), slope (if the ground is not level), sag (if across a valley), and also for height above sea (if not at sea level).

Some suitable and prominent object, C, visible from A and B, is then fixed upon. A theodolite, which is an instrument for measuring angles, is now fixed at A and B respectively, and the angles BAC and ABC are determined.

The angle ACB is equal to $180° - (\angle BAC + \angle ABC)$.

The three angles of the triangle are thus known, and the lengths of the sides of the triangle may be obtained from the following trigonometrical formula :—

$$\frac{\text{Sin A}}{\text{BC}} = \frac{\text{Sin B}}{\text{AC}} = \frac{\text{Sin C}}{\text{AB}};$$

$$\text{that is, } AC = AB \times \frac{\text{Sin B}}{\text{Sin C}},$$

$$\text{and } BC = AB \times \frac{\text{Sin A}}{\text{Sin C}}.$$

Thus the lengths of the three sides are obtained, and from these lengths the area of the triangle may be readily computed, for the area of the triangle $= \sqrt{s(s-a)(s-b)(s-c)}$, where s=half the sum of the sides a, b, and c.

It will have been noticed that the area is thus obtained without traversing the sides AC, BC of the triangle.

BC is then taken as the base of a second triangle, the angles at B and C are then measured with reference to some object, D, and the surveyor proceeds to find the area of this triangle as before. It is obvious that other triangles, *e.g.*, BDE may be similarly formed to cover the country as required.

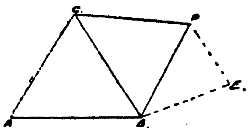


FIG. 36.
TRIANGULATION MAP.

Traverses.—If the student wished to survey a portion of his own neighbourhood, he would not use the above method, but would use the method of traverses. He would measure completely round the portion of land in question with a tape, or better still, with a steel chain.

Gunter's Chain is the one mostly used by land surveyors, because by it *areas* may be readily computed. It is 66 feet in length, and is divided into 100 equal parts, called links (7·92 inches). An acre of land is equal to 10 square chains, *i.e.*, 10 chains long and 1 wide.

The 100 feet Chain is another kind of chain which is very useful for road and engineering survey work, and for these purposes is superseding the Gunter's Chain. Each link of this chain is 1 foot in length.

Both chains consist of 100 links and every tenth link is distinguished by a brass tablet of a different shape, as shown in the diagram.

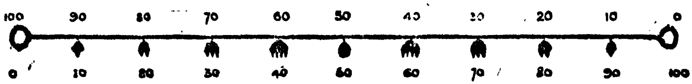


FIG. 37.—GUNTER'S CHAIN.

At a distance of 10 links from each end there is a brass tablet with 1 point; the tablet at 20 links has 2 points, at 30 it has 3 points, at 40 there are 4 points, and at 50 links, the centre of the chain, there is a circular tablet. Traverses may be carried out by either of the two following methods:—

1. Surveying with the chain only.
2. Surveying with the chain, aided by angular instruments of precision.

FIRST METHOD. CHAIN ONLY.

In the first method the laying down of the survey lines should be by triangulation, and in triangulating for a survey it is essential that each triangle should be well-conditioned, *i.e.*, it should, as near as possible, be equilateral. This is important,

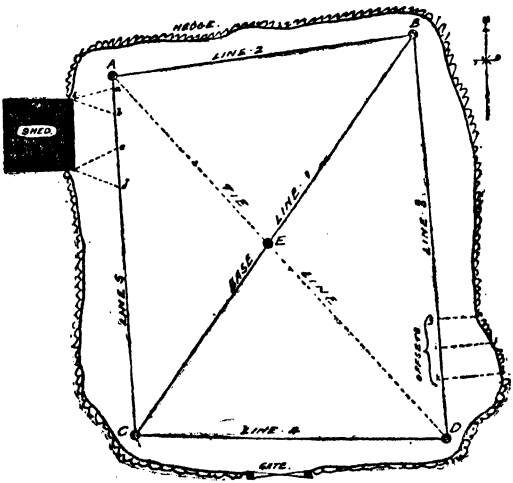


FIG. 38.
Method of surveying a field by means of the chain only.

and in laying out a survey, after making a reconnaissance of the ground, careful consideration should be given to this condition in deciding upon the survey lines. In laying out the survey lines a line should be taken across the whole length of the ground and should pass through the centre as near as possible. This line is termed the *base line* of the survey. The following diagram illustrates the method of surveying a field with the chain only. The stations B and C should first be decided upon in convenient positions, so that a clear and uninterrupted view and course is between them, and the base line BC then laid out and carefully measured. The direction of this base line in relation to the magnetic north should be taken. This may roughly be done by means of an ordinary compass where the card is not fixed to the needle. The method is as follows:--Hold the compass in the line BC so that the north and south points of the compass card are directly in line with the points B and C. The angle which this line makes will obviously give the direction of BC with regard to the north. The stations A and D should then be set out, thus dividing the field into two triangles ABC and BCD, with the common base BC. The lines AC, CD, DB, and BA are now measured, and a line is drawn from A to D, and the distances AE, CE, and ED are carefully noted to check the triangulation on the base BC. At the north-west corner of the field there is a shed, and this is measured on the line AC, the distances of *a*, *b*, and *c* along this line being noted in the survey book, and also the measurements *ae*, *be*, *bd*, and *cd*. This operation is termed "tieing in," and is the most accurate method for locating the surroundings of a chain line. On the line BD the method of taking offsets is illustrated, the lines *gh*, *ij*, and *kl* being at right angles to BD. The length of these lines and the distances of the points *g*, *i*, and *k* along the line BD are noted in the survey book. This method is generally adopted to locate the positions of hedges or other irregular boundaries. Offsets are often made by means of a large set-square, but a quick and easy method of setting out a right angle is shown in the diagram. From the line BD it is required to set out a line *fg* at right angles. To do this, measure forty links from the point *f* towards *h* in the

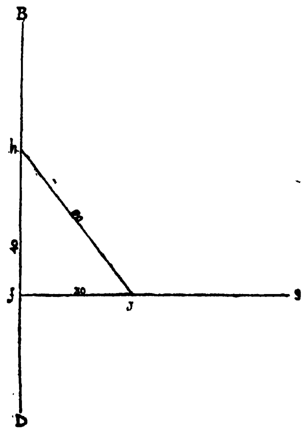


FIG. 39.
SETTING OUT A RIGHT ANGLE.

lines BD. Then hold one end of the chain at *f*, and also hold the 80-links mark at *h*. Then take the 30-links mark and pull tight into position at *j*, the line *fj* will be at right angles to the line BD. This is an application of the well-known proposition of Euclid I. 47 to actual practice.

SECOND METHOD. CHAIN AND THEODOLITE.

The instrument generally used by surveyors for the measurement of angles in land surveying is the theodolite. The great advantage of this method of surveying is its speed and accuracy, as the measurement of tie or other lines such as BC and AD is unnecessary. For example, if, in the diagram shown, the angles at A, B, C, and D are taken and the four sides measured, the survey can be at once plotted. The value of taking these angles

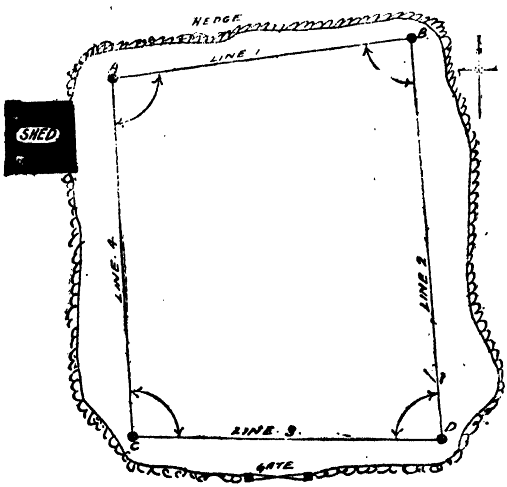


FIG. 40.
FIELD SURVEY WITH CHAIN AND THEODOLITE OF SCHOOL.

is that the correctness of the angles can be checked as "the sum of the interior angles of any rectilinear figure is equal to twice as many right angles as the figure has sides less four right angles."

PLAN OF ROOM.

The student should make a plan of his class-room upon squared paper.

Method:—

1. $\frac{1}{4}$-inch to the foot is a convenient measure to adopt.
2. Find the magnetic North and South direction by means of a compass, and draw a line representing this direction on the plan.
3. Ascertain the lengths of the walls of the rooms by means of a tape measure, and draw lines to scale to represent these lengths on the plan in their relative directions.
4. Now observe the positions and dimensions of the desks and other furniture and represent them on the plan as shown in the accompanying sketch.

A CLASS-ROOM.

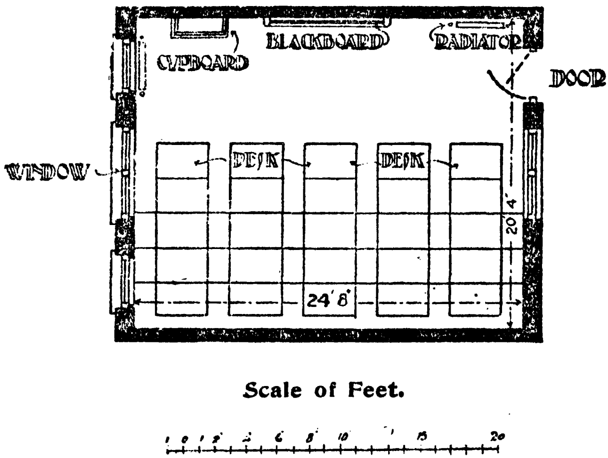


FIG. 41.—SKETCH OF ROOM.

PROJECTIONS.

Take a piece of paper, wrap it round an orange, and observe whether the entire paper touches the surface of the orange at all points. From this experiment it will be obvious that the

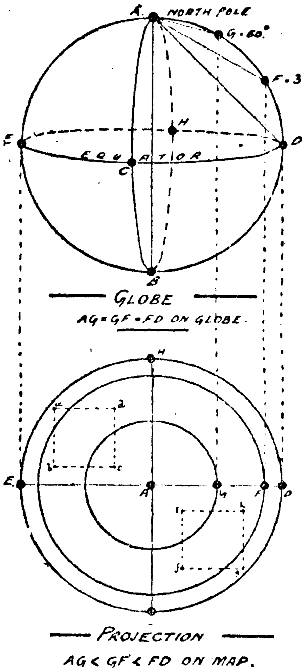


FIG. 42.
EQUAL-AREA PROJECTION.

earth, being a sphere, cannot have its spherical surface accurately represented on a flat sheet of paper, and therefore all our maps are more or less inaccurate.

Thirty or even more projections have been devised for representing the spherical surface of the earth on a flat piece of paper, each one claiming superiority over the rest in some particular.

We shall consider three kinds of projections.

1. **The Equal Area Projection,** which is accurate in area, but is inaccurate in distance and shape.

2. **The Equiangular Projection,** which is accurate in shape, but is inaccurate in distance and area.

3. **The Equidistant Projection,** which is accurate in distance, but is inaccurate in shape and area.

The Equal Area Projection.—Let AEBD represent the Globe. To obtain an equal area projection of this globe, draw a circle with AD as radius, the circumference ECDH representing the equator. Mark the points, F and G, on the circumference AD of the globe to represent places thirty and sixty degrees north of the equator respectively. To project these points take the radius AF and AG respectively, and draw concentric circles within ECDH from A as centre.

Suppose the square *abcd* on the projection or map represents one thousand square miles, then any other square of the same size, for example, *efgh* on the map, will represent one thousand square miles also.

It is evident, however, that in this projection, equal lengths in different parts of the map do not represent equal distances on the earth's surface. ECDH in the above projection is 3¼ times greater than CAH, while ECDH on the above globe is only *twice* the length of CAH. Thus it is proved that distance in an equal area projection is inaccurate.

In transferring shapes from the spherical surface to such a map, the lengths at right angles to the parallels of latitude must be diminished to a greater extent than similar lengths along those parallels. This necessitates an alteration of the shape during the transference. A knowledge of advanced mathematics is required to fully understand the reason for the defects in this projection, but the process may be roughly compared to the fitting of squares into oblongs of equal area; for example, the fitting of a square of six inches side into an oblong nine inches long and four inches broad.

The Ordnance Survey 1-inch maps of Scotland and Ireland are equal area projections.

Equiangular Projection.—From an examination of the lines of latitude and longitude on a globe, it may readily be observed that the length of a degree of latitude is constant, ignoring the slight flattening at the Poles, *e.g.*, EF=GH in Fig. 42. A degree of longitude varies in length according to its position. At 60 degrees north or south of the Equator, the length of a degree of longitude is only half the length of a degree at the Equator, *e.g.*, AB=½CD in Fig. 42.

Now we might endeavour to preserve the proportion between degrees of latitude and longitude by drawing lines on a map at right angles, keeping the lengths of the *degrees of latitude constant* and varying the lengths of the degrees of longitude, but on such a map it is obvious that the North Pole could not be represented. On the other hand, we might preserve the proportion by keeping the lengths of the *degrees of longitude constant* and varying the lengths of the degrees of latitude, and this is the method adopted in the well-known **Mercator's Projection.** The lengths of the degrees of latitude are increased towards the Poles, so that they keep the same proportion as the degrees of *longitude* bear to the degrees of latitude on the globe.

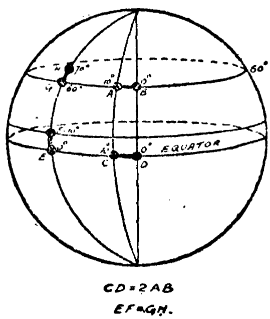


FIG. 43.
EQUIANGULAR PROJECTION.

The advantages of the Mercator's system are:—

1. The directions are accurate. If a point is situated to the north-east of another point on the map, it may be reached by going to the north-east from the latter place, though this route would not be the shortest unless it happened to fall on a *great circle.* The student may prove this for himself by drawing a straight line on a Mercator's map from London to Pekin. Such a line would pass through the Caspian Sea and Russian Central Asia. This, however, is not the shortest route from London to Pekin, the shortest route being through Siberia, as is indicated by the curved line from London to Pekin in the accompanying diagram. Now take a globe, mark the position of London and

MERCATOR'S PROJECTION

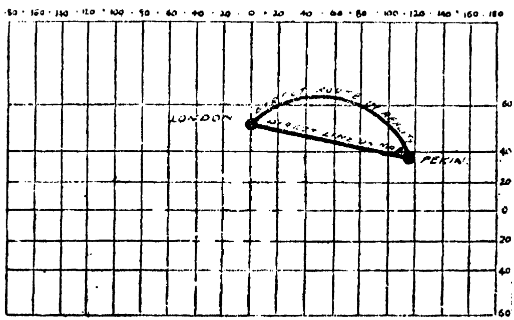


Fig. 44.

Pekin respectively, and draw the shortest line between those two towns. This line, it will be observed, does not pass through the Caspian Sea, but lies much farther to the north, and is in the direction of a *great circle.* The plane of a *great circle* is one which divides the earth into two equal portions.

2. All the world can be represented on one sheet.

3. The correct *shapes* are preserved, on the principle that we may represent the same object, *e.g.*, a chair in different sizes but similar in shape.

The disadvantages of the Mercator's Projection are:—

1. The areas to the north and south of the equator are not in proportion but are greatly exaggerated. Greenland, for instance, is represented as having an area many times greater than that of

India, notwithstanding that the areas of these two countries are equal. It is impossible, therefore, to have a *scale* for Mercator's map. The north polar regions on such a map must be exaggerated infinitely, and therefore cannot be represented.

2. A straight line drawn between two places on the map does not necessarily indicate the shortest distance.

3. Distance is inaccurate and most misleading to one who has not studied geography by means of a globe.

Equidistant Projection.—In this projection any point of the sphere is taken as the centre of the map (A, for instance, in the accompanying diagram). Great circles through this point are represented by straight lines of the true length to scale, and they intersect each other at right angles, as shown in the projection below.

The disadvantages of this system are that the areas and shapes of countries are not correct. Distances, when measured towards the centre of the map, are strictly accurate according to the scale, and distances at right angles to these are also approximately correct.

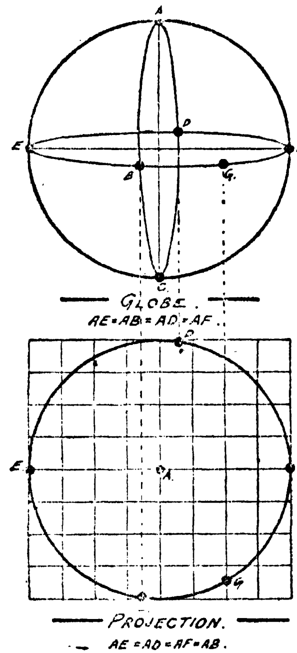


FIG. 45.—EQUIDISTANT PROJECTION.

Atmosphere.—The atmosphere is a gaseous envelope surrounding the earth, and extends to a height of more than two hundred miles. It is a mixture of nitrogen and argon 79%, oxygen 20·96%, carbon dioxide ·04%, and traces of ammonia, water vapour, and other gases. The amount of water vapour present in the atmosphere is of the utmost importance, for upon this the rainfall chiefly depends. The quantity of water vapour that can be absorbed by the air is largely dependent on temperature. A cubic foot of air at a temperature of 30°F. is saturated with two grains of water vapour, but at 70°F. it can hold eight grains.

The instruments employed in estimating the quantity of water vapour in the air are the wet-bulb and dry-bulb thermometers. The wet-bulb thermometer is similar to an ordinary thermometer, excepting that its bulb is covered with muslin which is kept moist by threads that dip into water. The evaporation of the moisture from the muslin lowers the temperature of the bulb in proportion to the rate of evaporation. This rate is more rapid if the air is dry, and under such conditions the temperature registered by the thermometer is greatly decreased, and is consequently much lower than that registered by a dry bulb or ordinary thermometer. When the difference between the readings of a wet-bulb and a dry-bulb thermometer is great, the air is *dry*, but when the readings are similar, the atmosphere has reached its point of saturation.

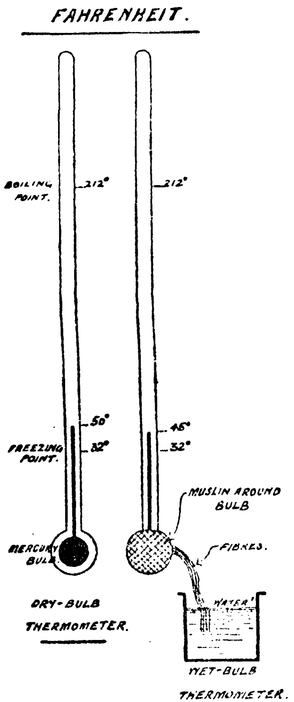


FIG. 46.
DIFFERENCE BETWEEN READINGS.

Dew.—Should the air be cooled after it has reached its point of saturation, some of the water-vapour it contains becomes visible and is known as *dew*, *fog*, *mist*, or *cloud*. Dew is generally formed at night, owing to the cooling of the surface of the earth and the consequent lowering of the temperature of the layers of atmosphere in contact with it. Much of the moisture that appears as dew arises from the earth itself. It is evident that the quantity of dew will depend upon the degree of humidity of the atmosphere and also upon the amount of heat radiated from the surface upon which the dew is formed. Good radiating surfaces, such as blades of grass, sand, and glass, are favourable to the formation of dew. The temperature at which the dew begins to fall is called the *dew-point*, and this temperature can be estimated from the readings of dry-bulb and wet-bulb thermometers, provided that corrections are made according to Glaisher's Hygrometrical Tables.

EXAMPLE.—Dry-bulb reading 50°.
Wet-bulb reading 45°.
Difference between readings 5°.
Glaisher's correction for 5° difference when dry-bulb is 50° is 5°·3, and this must be subtracted from the wet-bulb reading, which gives 39°·7 as the dew-point.

Fog and Mist.—Fog and Mist are caused by the condensation of the water-vapour in those layers of the atmosphere which are at no considerable height. Mist particles of moisture are slightly larger than fog particles.

Cloud.—When the moisture of the atmosphere appears in a state of suspension at a great height, it is called a cloud. The various forms of clouds are useful for determining weather forecasts and have received the following names and descriptions from the International Meteorological Committee:—

CIRRUS or Mare's Tail (Ci), 21,000 to 50,000 feet high. Detached clouds, delicate and fibrous-looking, taking the form of feathers, generally of a white colour. Sometimes arranged in belts which cross a portion of the sky in "great circles," and, by an effect of perspective, converge towards one or two opposite points of the horizon.

NIMBUS or Rain-cloud (N), 4,500 to 6,000 feet high. A thick layer of dark clouds, without shape and with ragged edge, from which continued rain or snow generally falls. If the layer of Nimbus separates up into shreds, or if small loose clouds are visible floating at a low level, underneath a large Nimbus, they may be called Fracto-nimbus (the "Scud" of sailors).

CUMULUS or Wool-Pack Clouds (Cu), 3,000 to 6,450 feet high. Thick clouds, of which the upper surface is dome-shaped, and exhibits protuberances, while the base is horizontal.

These clouds appear to be formed by a diurnal ascensional movement, which is almost always observable. When the cloud is opposite to the sun, the surfaces usually presented to the observer have a greater brilliance than the margins of the protuberances. When the light falls aslant, these clouds give deep shadows; when, on the contrary, the clouds are on the same side as the sun, they appear dark, with bright edges. The true Cumulus has clear upper and lower limits. It is often broken up by strong winds, and the detached portions undergo continual changes. These may be distinguished by the name of Fracto-cumulus.

STRATUS—(S) 0 to 3,500 feet high. A horizontal sheet of lifted fog. When this sheet is broken up into irregular shreds by the wind, or by the summits of mountains, it may be distinguished by the name of Fracto-stratus.

Modifications of the above four principal forms are:—

Cirro-stratus (Ci-s).—A thin whitish sheet at times completely covering the sky and only giving it a whitish appearance, or at others presenting more or less distinctly a formation like a large tangled web. This sheet often produces halos around the sun and moon.

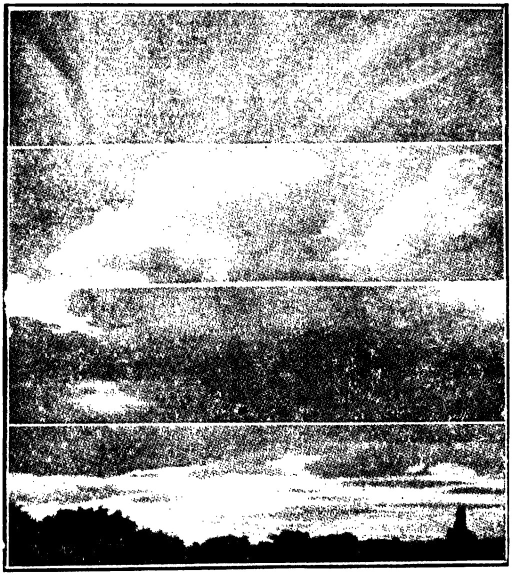
Cirro-cumulus (Ci-cu).—Mackerel sky 10,000 to 23,000 feet high. Small globular masses or white flakes without shadows, or having very slight shadows, arranged in groups and often in lines.

Alto-cumulus (A-cu).—10,000 to 23,000 feet high. Largish globular masses, white or greyish, partially shaded, arranged in groups or lines, and often so closely packed that their edges appear confused. The detached masses are generally larger and more compact at the centre of the group; at the margin they form into finer flakes. They often spread themselves out in lines in one or two directions.

Alto-stratus (A-s).—10,000 to 23,000 feet high. A thick sheet of a grey or bluish colour, which shows a brilliant patch in the neighbourhood of the sun or moon, and which, without causing halos, may give rise to coronae. This form goes through all the changes like the Cirro-stratus, but by measurements made at Upsala, its altitude is one-half less.

Strato-cumulus (S-cu).—About 6,500 feet high. Large globular masses or rolls of dark cloud, frequently covering the whole sky, especially in winter, and occasionally giving it a wavy appearance. The layer of Strato-cumulus is not as a rule very thick, and patches of blue sky are often visible through the intervening spaces. All sorts of transitions between this form and the Alto-cumulus are noticeable. It may be distinguished from nimbus by its globular or rolled appearance, and also because it does not bring rain.

Cumulo-nimbus (Cu-n).—The Thunder Cloud; Shower Cloud; Storm Cloud; 4,500 to 24,000 feet high. Heavy masses of cloud, rising in the form of mountains, turrets, or anvils, generally having a sheet or screen of fibrous appearance above (False Cirrus), and underneath a mass of cloud similar to nimbus. From the base there usually fall local showers of rain or of snow, occasionally hail or soft hail. Sometimes the upper edges have the compact form of cumulus, forming into massive peaks round which the delicate "false cirrus" floats, and sometimes the edges themselves separate



1

2

3

4

CLOUD CHART. [*To face p. 52.*

(1) Cirrus. (2) Cumulus. (3) Nimbus. (4) Stratus.

into a fringe of filaments similar to that of the cirrus cloud. This last form is particularly common in Spring showers. The front of thunder clouds of wide extent frequently presents the form of a large bow spread over a portion of the sky which is uniformly brighter in colour.

Rainbows.—Rainbows are formed by the decomposition of the rays of the sun as they enter drops of rain, and the subsequent reflection of these decomposed rays from the inner surfaces of the drops. There are often two or more rainbows visible in the clouds opposite the sun at the same time, and they are dependent on the sun's height.

The brightest and lowest rainbow of the series is called the *Primary* one, and in it the colours of the spectrum—red, orange, yellow, green, blue, indigo, and violet—can be distinguished, the red band forming the *outer* edge. In the fainter or *Secondary* rainbow the order is reversed, the violet band being outermost.

As the sun's height is increased, the position of the rainbow is lowered, so that when the sun is more than 42° above the horizon, the primary bow disappears altogether, though the secondary one may be seen when the sun is at any height less than 54°. Rainbows are therefore only visible either in the morning or evening.

Rainfall.—Warm air can hold a greater quantity of water vapour than cold air. Consequently, when moist air is driven into a colder latitude or to a higher altitude, there is a tendency for the moisture to be precipitated in the form of rain, hail, or snow. The moisture in the air is due to the process of evaporation which is constantly going on at the earth's surface, especially in the oceans, lakes, and rivers. Winds blowing from the ocean usually contain a large quantity of moisture, and should they eventually reach a mountainous or colder region, will probably produce rain. This is the reason why our South-West Winds, which are warm and moist, and which prevail throughout the British Isles, are often accompanied by rain, especially in the districts first reached and those which are most elevated, for example, South-West Ireland, the Western Highlands of Scotland, the Cumbrian Mountains, and the Mountains of Wales. In the districts mentioned the mean annual rainfall is upwards of 60 inches, that is, the rain, if allowed to remain on the ground where it falls, would cover those districts to a depth of more than 60 inches.

Rain-gauge.—A rain-gauge is the instrument generally used to estimate the amount of rainfall. It consists of a cylinder containing a funnel and a can, as in diagram. It should be put firmly in the ground in an open situation with the rim of the cylinder one foot above the surface. It is customary in this country to take rainfall measurements at 9 a.m. daily. The rain which has collected in the can is poured into a measuring glass, which holds half an inch of rainfall, and is graduated to indicate tenths and hundredths of an inch. ·1 of an inch is about the average daily rainfall in this country.

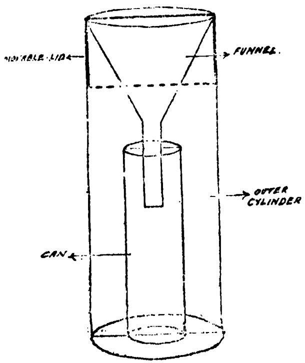


FIG. 47.—RAIN-GAUGE.

Snow.—If the temperature is so low that snow falls instead of rain, the rain-gauge is still employed to estimate the quantity. It may be necessary to melt the snow which has collected at the top of the gauge with warm water. The quantity of warm water added must afterwards be carefully deducted from the water found in the can.

Another method of determining the "rainfall" when it consists of snow is to invert the top of the rain-gauge over the undrifted snow which has fallen during the preceding 23 hours, to turn it round quickly, to lift the snow thus enclosed, and to ascertain the amount by melting, as described above. A foot of snow is roughly equivalent to one inch of rain. An inch of rain on an acre represents a downfall of 101 tons of water.

Rainfall measurements should be represented on squared paper, and the student should compile a table similar to the following for his own district:—

MONTHLY RAINFALL OF LONDON FOR 1907

January	1·09 inches.	July	·97 inches.
February	1·27 ,,	August	2·35 ,,
March	·90 ,,	September ..	·63 ,,
April	3·48 ,,	October	3·44 ,,
May	1·46 ,,	November	4·13 ,,
June	2·64 ,,	December	2·17 ,,

This rainfall of .24·71 inches for London is roughly equal to the average yearly amount. The average yearly amount for England is 31·5 inches. The town of Cheadle in North Stafford-

FIG. 48.—MONTHLY RAINFALL—LONDON, 1907.

shire has this amount. Seathwaite in Cumberland has an average annual rainfall of 131·3 inches, and a comparison should be made between the table given below and that of London.

MEAN MONTHLY RAINFALL OF SEATHWAITE.

January	13·2 inches.	July	9·3 inches.
February	11·2	August	11·7 ,,
March	10·5	September	12·4 ,,
April	6·8	October	12·2 ,,
May	7·4	November	14·1 ,,
June	6·5	December	15·8 ,,

The amount of rainfall in England has been carefully estimated by Dr. H. R. Mill, whose results are shown in the following table:—

19·5%	of England's	surface has	a rainfall	under 25 inches.
37·1%	,,	,,	,,	between 25 and 30 inches.
30·7%	,,	,,	,,	,, 30 ,, 40 ,,
11·2%	,,	,,	,,	,, 40 ,, 60 ,,
1·4%	,,	,,	,,	over 60 ,,

The driest portion of England is the inland region of the Eastern Plain, more particularly the county of Cambridge. The heaviest rainfall occurs at Seathwaite, where as much as 150 inches is sometimes registered. Other humid areas are the mountainous districts.

The rainfall of the British Isles is heaviest in the west, the rainfall for the various countries being:—Wales, 49·5 inches; Scotland, 47 inches; Ireland, 42·5 inches; and England, 31·5 inches.

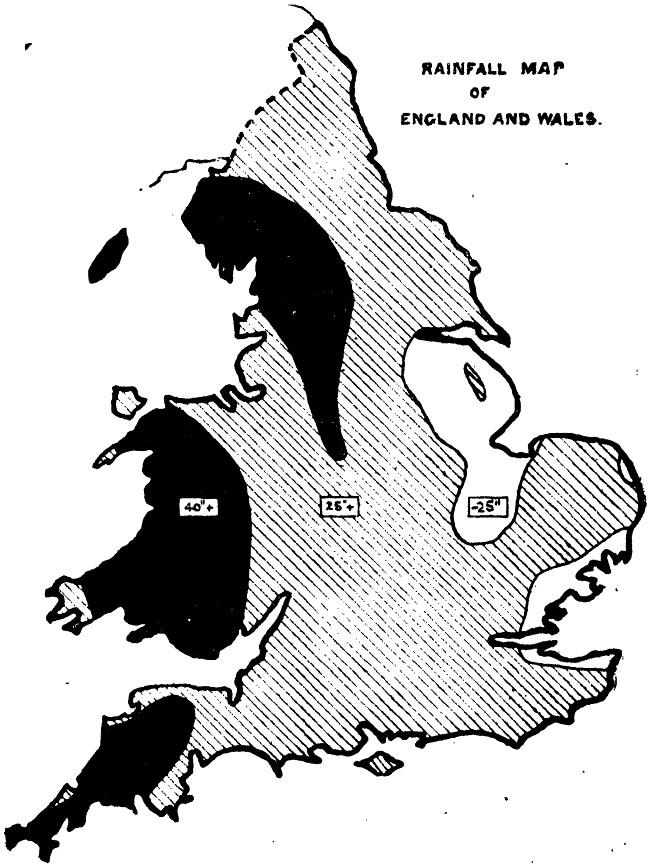


FIG. 49.

The comparatively heavy rainfall of Wales is due to the fact that the prevailing winds come from the Atlantic, laden with moisture which is precipitated on the cool slopes of the high mountains.

European Rainfall.—The eastern portion of the continent of Europe, being less subject to the influence of the sea than the west, has a much less rainfall than the west. The rainfall is approximately 40 inches in the west and 20 inches in the east. The mountainous regions have the heaviest rainfall. The

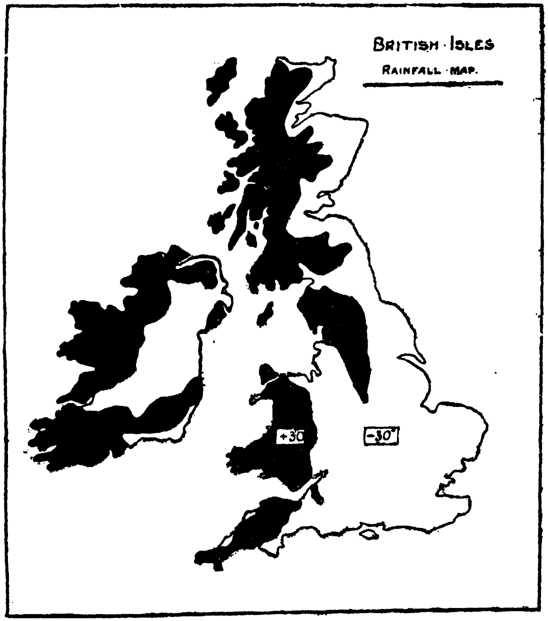
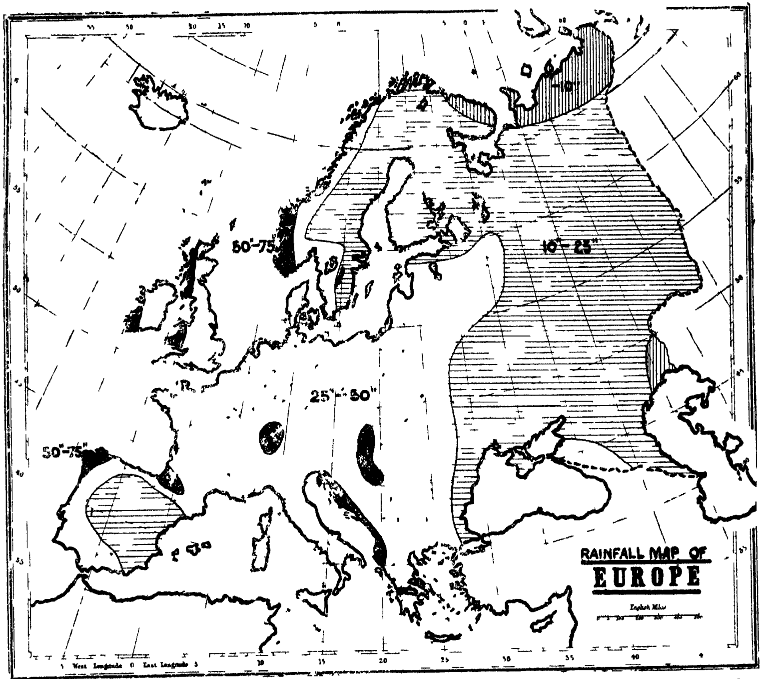


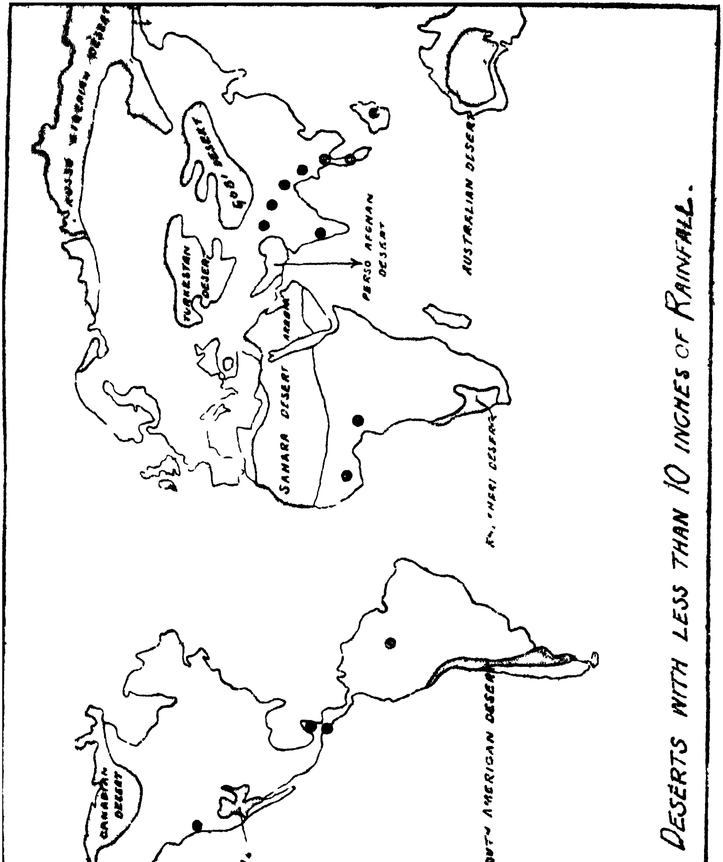
FIG. 50.

tablelands have less rain than mountains at a corresponding height, owing to the winds having been deprived of their moisture by the *escarpments* of the tablelands, *e.g.*, Spain.

The World's Rainfall.—The regions of heaviest rainfall in the world are in the path of moisture-laden winds from the neighbouring oceans, and are generally situated at a great height,


RAINFALL MAP OF
EUROPE
English Miles
50"-75"
50"-75"
25"-50"
10"-25"
-10"
West Longitude 0 East Longitude

[To face p 56



DESERTS WITH LESS THAN 10 INCHES OF RAINFALL.
WETTEST PARTS.
CANADIAN DESERT
DESERT OF UTAH.
SOUTH AMERICAN DESERT
SAHARA DESERT
ARABIA
PERSO AFGHAN DESERT
TURKESTAN DESERT
GOBI DESERT
RUSSO SIBERIAN DESERT
AUSTRALIAN DESERT

FIG. 51.

e.g., the hilly districts of India. The heavy rainfall in the Congo and Amazon basins is due, to a great extent, to the luxuriant vegetation, which retains the moisture instead of allowing it to percolate through the soil and drain away, and also to the great amount of evaporation. Some large tracts of country in various parts of the world have become wholly desert through the reckless destruction of trees by the inhabitants.

Inland countries, *e.g.*, Turkestan, have often a scanty rainfall, because the winds, blowing from some far distant ocean, have been deprived of their moisture by intervening highlands. The winds blowing from the ocean into the Sahara become raised in temperature, their capacity for moisture is consequently greater, and there is, therefore, no tendency towards precipitation. The reasons given should be applied to the comparatively rainless regions shown in the map on page 58.

Atmospheric Temperature.

Temperature is estimated by means of thermometers, of which there are two kinds in common use, *viz.*, the centigrade thermometer, for scientific purposes, with 0° as freezing point and 100° as boiling point, and the Fahrenheit thermometer, for ordinary and meteorological purposes, with 32° as freezing point and 212° as boiling point. 180 divisions on the Fahrenheit scale therefore correspond to 100 divisions on the Centigrade scale, and by the correct use of this ratio (9 : 5), and due allowance for the 32, temperatures Fahrenheit may be converted into temperatures Centigrade.

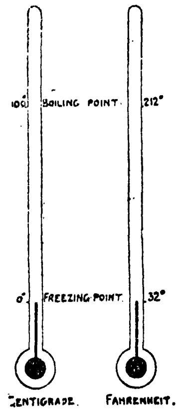


FIG. 52.
THERMOMETERS.

RULE.—Temperature (Fahrenheit) $= \frac{9}{5}$C. $+ 32$.
,, (Centigrade) $= \frac{5}{9}$(F. $- 32$).

EXAMPLE.—*Convert 10°C. into the Fahrenheit scale.*
Fahrenheit $= (\frac{9}{5} \times 10) + 32 = 50°$.
$\therefore$ 10°C. $=$ 50°F.

Atmospheric temperatures are usually recorded in the Fahrenheit scale. Such temperatures should be taken daily, and a graph could then be drawn and compared with the following one:—

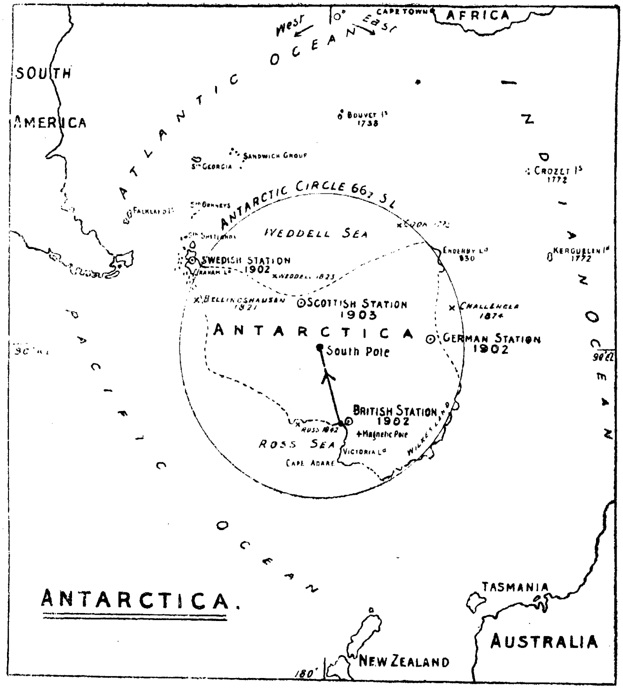
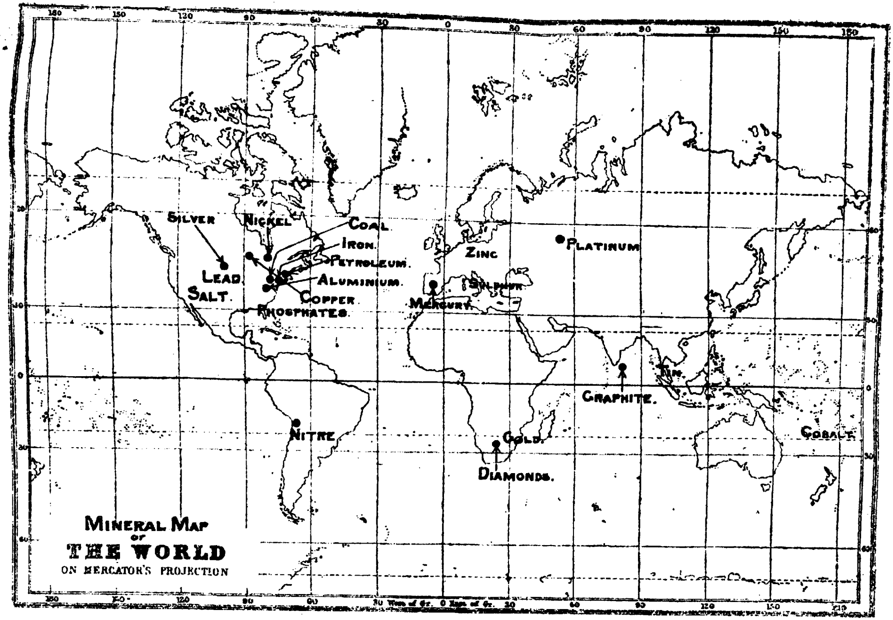


Fig. 77.

[To face p. 84.


MINERAL MAP
OF
THE WORLD
ON MERCATOR'S PROJECTION
SILVER
NICKEL
COAL
IRON
PETROLEUM
ALUMINIUM
COPPER
PHOSPHATES
LEAD
SALT
NITRE
ZINC
SULPHUR
MERCURY
PLATINUM
GOLD
DIAMONDS
GRAPHITE
TIN
COBALT

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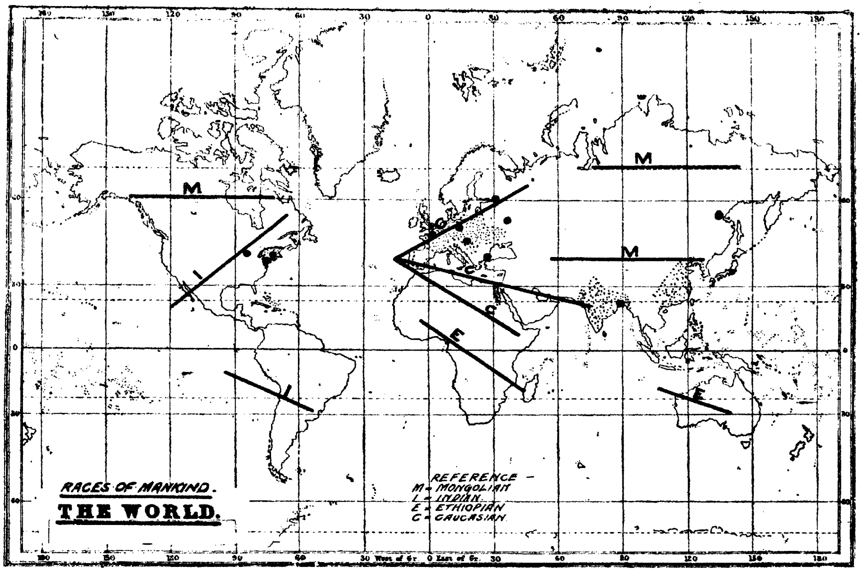

[*To face p. 122.*

The above map does not take *recent* immigration into account. The thirteen largest cities of the world (seven of them in Europe) are indicated by large black dots; the area of dense population by small dots.

MEAN DAILY TEMPERATURES AT LONDON FOR THE *Coldest* MONTH (JANUARY).

Jan.	1—38·6°	Jan.	11—37·9°	Jan.	21—38·8°
,,	2—38·4°	,,	12—37·9°	,,	22—38·8°
,,	3—38·3°	,,	13—38°	,,	23—38·9°
,,	4—38·3°	,,	14—38°	,,	24—38·9°
,,	5—38·2°	,,	15—38·1°	,,	25—39·1°
,,	6—38·1°	,,	16—38·3°	,,	26—39·3°
,,	7—38°	,,	17—38·5°	,,	27—39·5°
,,	8—37·9°	,,	18—38·6°	,,	28—39·6°
,,	9—37·9°	,,	19—38·7°	,,	29—39·7°
,,	10—37·9°	,,	20—38·8°	,,	30—39·7°
				,,	31—39·7°

From the above table it will be observed that the second week in January is the coldest in England (Greenwich).

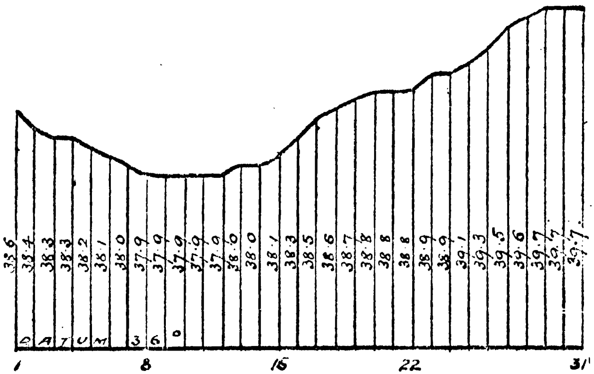

FIG. 53.—MEAN DAILY TEMPERATURES AT LONDON IN JANUARY.
Vertical scale, 2 degrees=1 inch.

The following are the mean daily temperatures at London during the *warmest* month (July):—

July	1—61°·5	July	11—62°·7	July	21—63°·2
,,	2— ·6	,,	12— ·9	,,	22— ·1
,,	3— ·8	,,	13—63°·1	,,	23—63°
,,	4—62°·1	,,	14— ·3	,,	24—62°·9
,,	5— ·3	,,	15— ·4	,,	25— ·7
,,	6— ·4	,,	16— ·4	,,	26— ·5
,,	7— ·4	,,	17— ·4	,,	27— ·4
,,	8— ·4	,,	18— ·3	,,	28— ·3
,,	9— ·4	,,	19— ·2	,,	29— ·3
,,	10— ·5	,,	20— ·2	,,	30— ·3
				,,	31— ·2

From the foregoing table it will be observed that the third week in July is the hottest week in the year. The coldest part of the day is immediately before sunrise, the warmest is in the

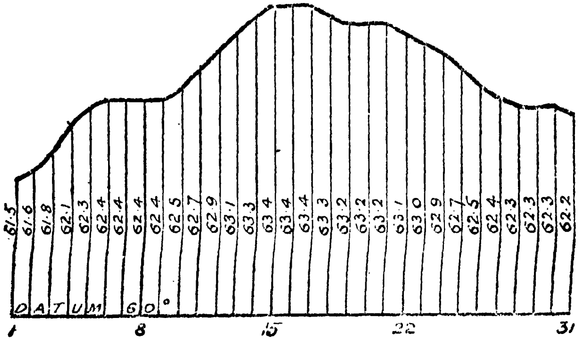

FIG. 54.—MEAN DAILY TEMPERATURE AT LONDON IN JULY. Vertical scale, 2 degrees = 1 inch.

afternoon between 1 p.m. and 2 p.m. The highest temperature in the shade recorded at Greenwich during the past 70 years was 96·6° in 1868, the lowest was 4° in 1841.

Maximum and Minimum Thermometers are employed for estimating maximum and minimum temperatures. The mercury in a maximum thermometer pushes a steel index along as the temperature rises. When the temperature falls, the mercury contracts and leaves the index behind, which thus registers the maximum temperature.

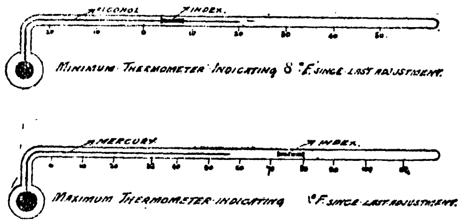

FIG. 55.—MAXIMUM AND MINIMUM THERMOMETERS.

Alcohol is the liquid used in minimum thermometers, because it remains liquid at very low temperatures. The index is put *into* the alcohol and cannot break through on account of the film which is formed at the free surface of the alcohol. The alcohol, when contracting, draws back the index, but is unable *to push it forwards when expanding. In this manner the index remains to register the minimum temperature since the last adjustment of the thermometer.*

The following is a table of the maximum and minimum daily temperatures at London in 1907:—

MONTH.	MAXIMUM.	MINIMUM.	MONTH.	MAXIMUM.	MINIMUM.
January ..	51°	22°·4	July ..	79°	42°·8
February ..	51°·4	23°·5	August ..	77°·5	44°·1
March ..	69°·4	24°·1	September..	82°·7	34°·5
April ..	68°	29°·1	October ..	68°	35°·6
May ..	81°	33°·5	November..	60°·3	29°·2
June ..	75°·7	43°·1	December..	54°·3	19°·8

The highest maximum daily temperature in 1907 was on September 25th. The mean temperature for that day, obtained by dividing the sum of the maximum and minimum temperatures by 2, was 64°·5, and this was nearly ten degrees higher than the average mean daily temperature for that date. The average mean temperature of any day for the last sixty years is found by dividing the sum of the mean temperatures of that day by 60.

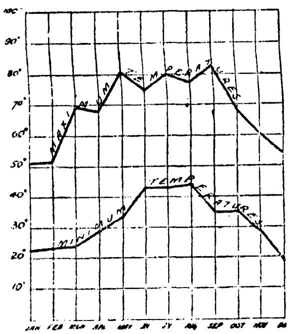

FIG. 56.
TEMPERATURE GRAPH OF LONDON.

CONDITIONS DETERMINING TEMPERATURE.

The chief conditions determining the temperature of a place are:—

(1) **Latitude.**—Places in or near the Tropics have usually a high temperature in consequence of the sun's rays being more direct. The annual range of temperature of such places is not great. In Singapore, for example, the temperature during the coldest month is 80° and for the warmest month 82°, a difference of 2° only.

(2) **Altitude.**—An increase of 300 feet in altitude causes a decrease of 1°F. in the temperature of the atmosphere. This decrease is due to the fact that heat radiated from the earth's mass is not felt to such an extent at a great height as it is at

the earth's surface. It is 15° colder at the top of Ben Nevis than at Fort William, which is situated at its base. The *snow-line* gradually rises from the poles, where it is at the earth's surface, to the tropics where it may be nearly 20,000 feet above sea-level. *The snow-line in the Alps is at a height of 8,800 feet.*

(3) **Distance from the Sea.**—Water takes in and gives out heat more slowly than land, with the result that places near the sea have their temperature raised in winter and lowered in summer. Inland places being removed from the modifying influence of the ocean, have comparatively cold winters and hot summers, and the climate is said to be continental; for example, Leicester has greater extremes of temperature than Yarmouth.

(4) **Winds.**—Prevailing winds greatly influence the temperature. The following effects of winds upon temperature have been observed at Greenwich:—

Wind.	Effect in Summer.	Effect in Winter.
North	Lowers temperature	Lowers temperature.
North-east wind ..	Lowers temperature slightly.	Lowers temperature.
East	Raises temperature.	Lowers temperature greatly.
South-east	Raises temperature.	Lowers temperature slightly.
South	Raises temperature very slightly.	Raises temperature greatly.
South-west	No effect.	Raises temperature greatly.
West	Lowers temperature	Raises temperature greatly.
North-west	Lowers temperature considerably.	Lowers temperature slightly.

(5) **Ocean Currents.**—The Gulf Stream raises the temperatures of the western countries of Europe, while the Labrador Current, which flows through the Arctic Ocean, lowers the temperature of the eastern shores of Canada.

(6) **Slope of a Country.**—If a country slopes *towards* the sun, *i.e.*, from south to north in the southern hemisphere, and from north to south in the northern hemisphere, the temperature is raised. On the other hand, if a country slopes *away from* the sun, the temperature is lowered. The excessive cold of Siberia

is largely due to the fact that the country slopes northwards towards the Arctic Ocean, *i.e.*, away from the sun.

(7) **Position of Mountain Ranges.**—The position of mountain ranges affects the temperature by keeping off either cold or hot winds. The rapid alternations of heat and cold in Central Canada are mainly due to the absence of protecting mountain ranges in the north.

Isotherms.—Isotherms are lines drawn on maps to connect places which have the same mean temperature, whether daily, monthly, or annual.

In drawing the isotherms of the British Isles an allowance of 1° for every 300 feet must be made for the difference in temperature caused by height of land, and the isotherms in the following maps represent sea-level temperatures:—

The principal facts to be observed respecting the isotherms of the British Isles are:—

1. The highest winter temperatures are in the West and South-West. This is due to the heat stored up in the relatively deep western seas. The seas radiate heat very slowly.

2. The highest summer temperatures are in the inland and south-eastern districts of England. This is due to the relatively high temperature of the continent of Europe in summer. The heat radiated from the Continent at that time affects the east of England more than the west. The North Sea is too narrow and shallow to counteract this influence to any great extent.

3. The isotherms over the land surface register a greater difference between the January and July temperatures than those over the water surface in corresponding latitudes. Take for example the line of latitude indicating 53° north in the adjoining map of January isotherms. In the St. George's Channel the temperature on this line is more than 42°, whilst at the town of Derby it is only 38°, *i.e.*, 4° *lower*.

In summer, however, the temperature of Derby is actually 2° *higher* than in the St. George's Channel, in a corresponding latitude, see Fig. 56.

4. The southern isotherms generally register a higher temperature than the more northerly isotherms, because the sun's rays are more nearly vertical at places in the south than at places farther north.

5. The isotherms of the British Isles approximate more nearly to a north-south direction in winter than they do in summer.

In summer they tend to an east-west direction. In the European isotherms a similiar result is noticeable, that is, the

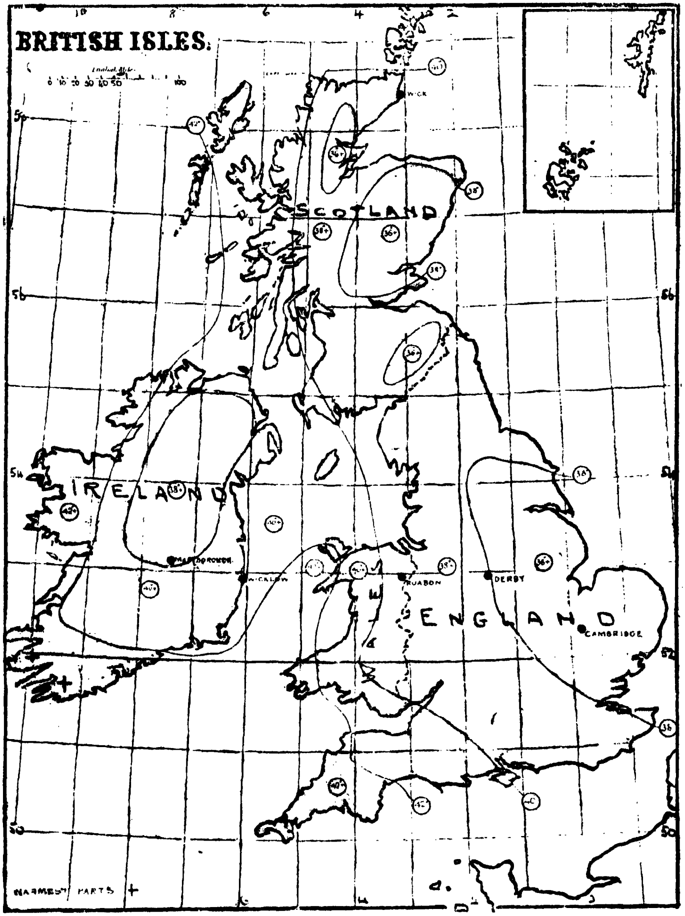

FIG. 57.—JANUARY ISOTHERMS, BRITISH ISLES.

land isotherms are to the south of corresponding water isotherms in winter, but are to the north of them in summer. The reason of this is that the water takes in and gives out heat more slowly than the land does. It also absorbs the heat to a greater depth.

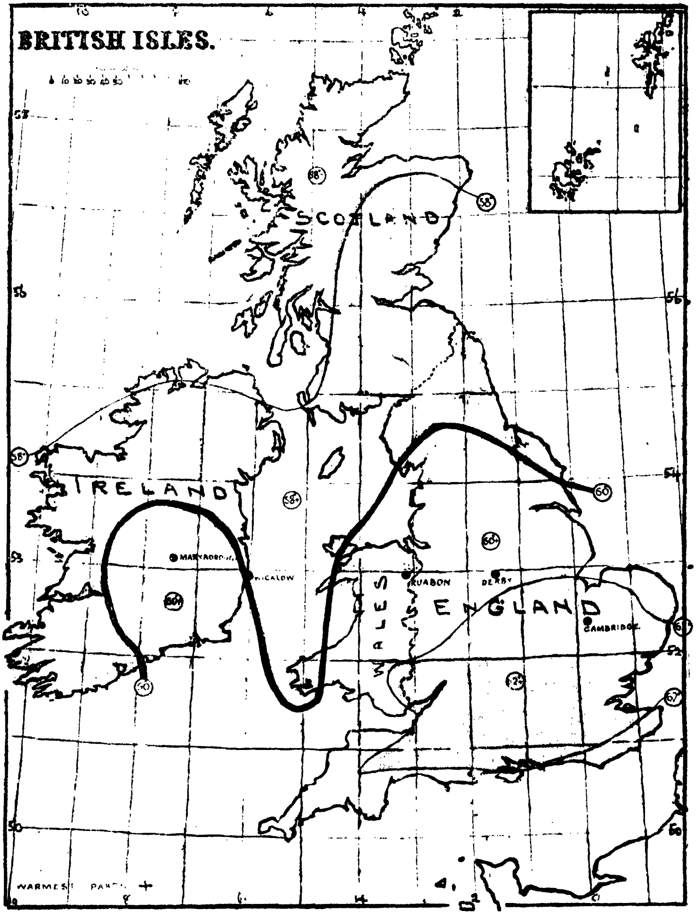

FIG. 58.—JULY ISOTHERMS, BRITISH ISLES.

The hottest parts of the world (see the Isothermal Chart of the World), namely, Utah, Sahara, Arabia, Persia, Aral, and Gobi in the Northern Hemisphere, together with Central Africa in the Southern Hemisphere, are crossed by either the Tropic of Capricorn in winter or the Tropic of Cancer in summer. This is due to the fact that the sun is vertically above Cancer and Capricorn in mid-summer and mid-winter respectively. Most of the hot districts mentioned above are tablelands, and this characteristic is an important contributing cause to their aridity.

ISOBARS.

Isobars are lines on maps drawn through places which have the same barometric pressure during similar periods of time. The atmospheric pressure is roughly 15 lbs. to the square inch at sea-level. The pressure of the atmosphere diminishes as we ascend above sea-level, and it is customary to make an allowance for height (one inch for every 900 feet) to reduce the isobars to the sea-level. A correction must also be made for the expansion or contraction of the mercury in the barometer caused by a change in temperature, and it is customary to reduce the readings to a temperature of 32°.

Barometers.—The barometer is the instrument employed to ascertain the pressure of the atmosphere. In the barometer tube is a column of mercury, supported by the atmosphere, the weight of the column being equivalent to the atmospheric pressure. A column of mercury averaging nearly 30 inches in height and one square inch in section is supported in London by the atmosphere, and such a column weighs 15 lbs.

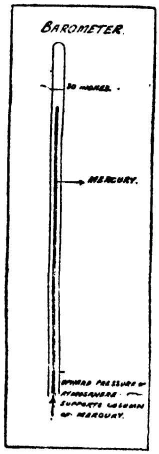

FIG. 59.

If the atmospheric pressure is diminished in consequence of greater height of land, greater quantity of aqueous vapour, increase in temperature, or the upward movement of air, the "barometer" falls, *i.e.*, the height of the mercury column is less.

The mercury column, at sea-level, has never been known to reach 32 inches, or to fall to 27 inches. The highest pressures are generally found a little to the north of the Tropic of Cancer and a little to the south of the Tropic of Capricorn.

From the following table of the mean barometric heights at London for the month of March it will be observed that the barometer usually stands between 29 and 30 inches. 30, 29, and 28 are abbreviated to 0, 9, and 8 respectively:—

MEAN BAROMETRIC PRESSURES. LONDON. MARCH

	INS.		INS.		INS.		INS.		INS.		INS.
1.	29·2	6.	9·8	11.	9·0	16.	9·1	21.	9·7	26.	9·8
2.	0·8	7.	9·8	12.	9·0	17.	9·5	22.	9·7	27.	9·5
3.	0·0	8.	9·9	13.	9·2	18.	9·6	23.	9·6	28.	9·8
4.	0·0	9.	9·4	14.	9·1	19.	9·9	24.	9·6	29.	9·7
5.	9·8	10.	9·4	15.	8·9	20.	9·8	25.	9·7	30.	9·7
										31.	0·0

Weather Charts.—By means of isobars, isotherms, and other meteorological observations, weather forecasts can be made. Meteorological observations from various parts of the British Isles are telegraphed to the Central Office in London, where the temperatures are plotted on maps, on which are also marked the velocity and direction of the wind, the state of the sky, and the places of rain or snow-fall. Isobars, representing each difference of one-tenth of an inch, are then drawn, and thus the areas of low pressure (*Cyclones*), and high pressure (*Anti-cyclones*) are enclosed. These areas are approximately circular in form.

The air moves from the Anti-cyclonic areas towards the Cyclonic areas, the intensity of the wind depending largely on the difference in the barometric readings. If the isobars are very close together, representing a steep *barometric gradient*, the velocity of the wind will be great. The force of the wind is chiefly felt in the Anti-cyclonic areas or areas of depression. Such areas are therefore subject to violent storms.

Comparatively calm, clear, cool weather prevails in the Cyclonic or High Pressure Areas. The direction of the wind is roughly parallel with the isobars, is anti-clockwise in the Cyclonic area, and clockwise in the Anti-cyclonic area. As a depression is usually accompanied by wet weather, the value of a weather forecast largely depends upon the prediction of the accurate path which a cyclone or depression area will take. In Europe a cyclone usually travels in a *north-easterly* direction. A practical rule for locating a cyclone is to face the wind, and the cylcone or storm-centre will probably be on the right-hand side.

Construction of a Weather Chart.—The barometric pressures at the various places marked on the map must first be plotted, and the highest pressure noted. North Shields on the accompanying map is the only town with a pressure of upwards of

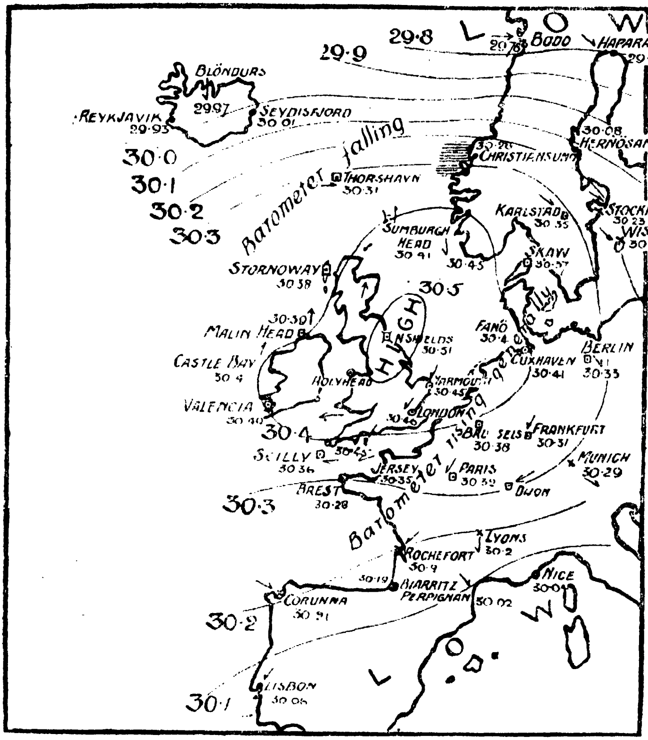

Fig. 60.—Weather Chart.

30·5 inches. Round this town the isobar 30·5 should be drawn. Now put small rings round all the towns which have a pressure between 30·4 and 30·5, and squares round all the towns which have a pressure between 30·4 and 30·3 as shown on the map.

It is obvious that the isobar 30·4 must be drawn in such a manner that Valentia, Holyhead, London, Cuxhaven, and North Shields are included, and that Scilly, Brest, Paris, Brussels, Frankfort, Berlin, Skaw, Karlstad, Thorshavn, Stornoway, and Malin Head are excluded.

Now "star" the towns with pressures between 30·2 and 30·3, *and it will then be evident that the isobar 30·3 must exclude Corunna, Rochefort, Lyons, Munich, Wisby, Stockholm, and Christiansund.*

Isobar 30·2 passes through Rochefort and Lyons, and includes Corunna, Munich, Wisby, and Christiansund. 30·1 must be drawn to exclude Lisbon, Perpignan, Nice, Hernösand, and Seydisfjord, while line 30·0 must exclude Reykjavik. Isobar 29·9 excludes Haparanda, and line 29·0 must exclude Reykjavik. Isobar 29·9 excludes Haparanda and line 29·8 excludes Bodö. It is now noted that Bodö has the lowest pressure on the map. It is therefore outside the Cyclonic area, and this fact should be indicated by the word **low**, written within the isobar 29·8. The isobar 29·9 is therefore the line of division between the Cyclonic area and the Anticyclonic area.

Winds.—The direction of the winds may then be inserted by arrows flying parallel to the isobars, in a clockwise direction in the Anticyclonic area, and in an anti-clockwise direction in the Cyclonic area. The isobars in the map are wide apart and the force of the wind is consequently slight.

Arrows, more or less complete, are used as significant of the force of the wind.

WIND SIGNS.

——⇀	Force, 1 to 3	>——>	Force, 8 to 10
——>	„ 4 „ 7	>>——>	„ above 10

BEAUFORT'S SCALE OF WINDS.

	SCALE.	
0.	Calm	2 miles per ho
1.	Light Air	4 „ „ „
2.	Light Breeze	7 „ „ „
3.	Gentle Breeze	10 „ „ „
4.	Moderate Breeze	14 „ „ „
5.	Fresh Breeze	19 „ „ „
6.	Strong Breeze	25 „ „ „
7.	Moderate Gale	31 „ „ „
8.	Fresh Gale	37 „ „ „
9.	Strong Gale	44 „ „ „
10.	Whole Gale	53 „ „ „
11.	Storm	64 „ „ „
12.	Hurricane	77 „ „ „

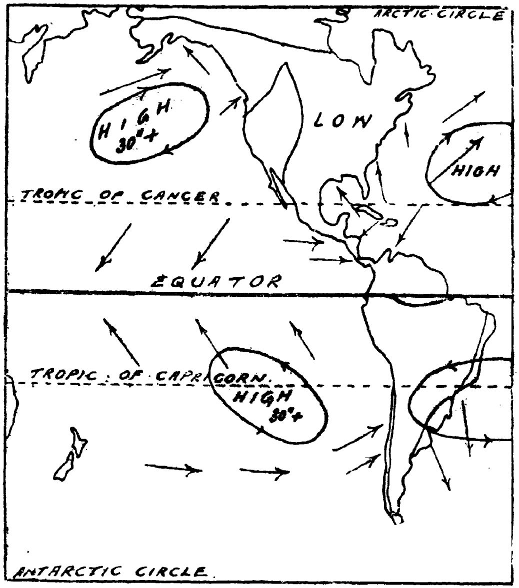

FIG. 61.—JULY ISOBARS REDUCED TO SEA LEVEL (New World).

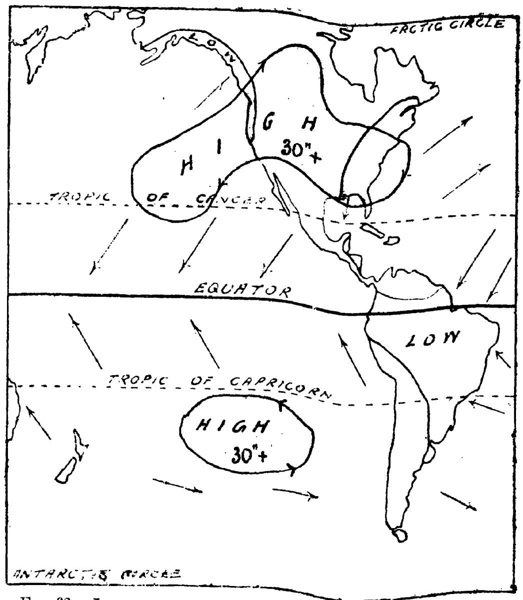

FIG. 62.—JANUARY ISOBARS REDUCED TO SEA LEVEL (New World).

[To face p. 70.

Isobars of the New World.

Rainy and Dry Seasons.

In *summer* there are two areas of high pressure in the northern Hemisphere, one over the Pacific Ocean, and the other over the Atlantic. From these Anti-cyclonic areas the winds blow outwards towards the land with a clockwise circulation, resulting in a comparatively heavy rainfall in North America, with the exception of the Utah Desert and other elevated districts in or near the Rocky Mountains. The low pressure area of the Mississippi induces moisture-laden winds from the Gulf of Mexico. (See Fig. 61.)

In *winter* the high pressure area is found over the *land*, and therefore the winds tend to blow outwards towards the sea, and there is consequently a diminished rainfall.

Now consider the regions south of the Equator during our summer. (See Fig. 61.) There is a belt of high pressure over Uruguay, the winds blow outwards towards the ocean, and this season is consequently the period of least rainfall. In winter the conditions are reversed, an area of low pressure prevails in Brazil, and the winds from the ocean bring an abundance of rain. Thus we find that in the southern, as well as in the northern regions, "the rain follows the sun."

Isobars of the Old World.

In *summer* the area of low pressure in the northern Hemisphere is over the land on account of its higher temperature. (See Fig. 64.) There is an inrush of cooler air from the surrounding oceans, and the whole of Eurasia, with the exception of the tablelands, the Mediterranean, and the Caspian regions, receives a fair quantity of rain. The inrush of this cooler air is especially noticeable in India, where the south-west monsoon causes torrential rains.

In the southern Hemisphere, on the other hand, the high pressure area is found over the South of Africa and Australia, with the result that those parts of the world have a scarcity of rain during the northern summer.

In *winter* there are areas of low pressure over Central Africa and North Australia, winds blow inland from the Indian and Pacific Oceans respectively, and heavy rains fall in Southern Congo and North-East Queensland. (See Fig. 63.)

Over Eurasia there is generally a high pressure area in winter, and winds do not tend to blow inland from the neighbouring oceans, Russia and other inland countries receiving very little

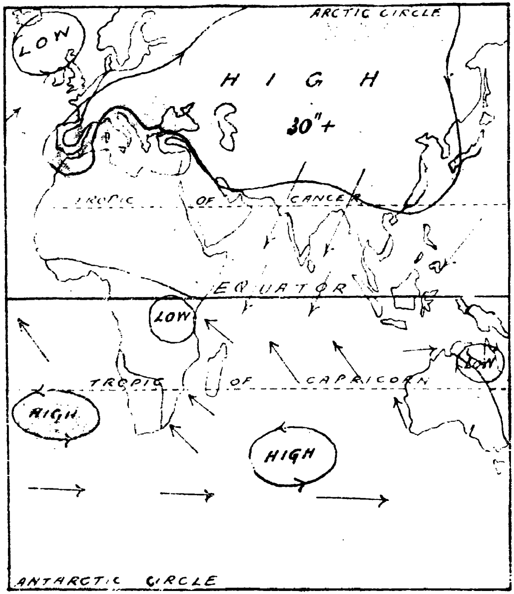

FIG. 63.—JANUARY ISOBARS REDUCED TO SEA LEVEL (Old World).

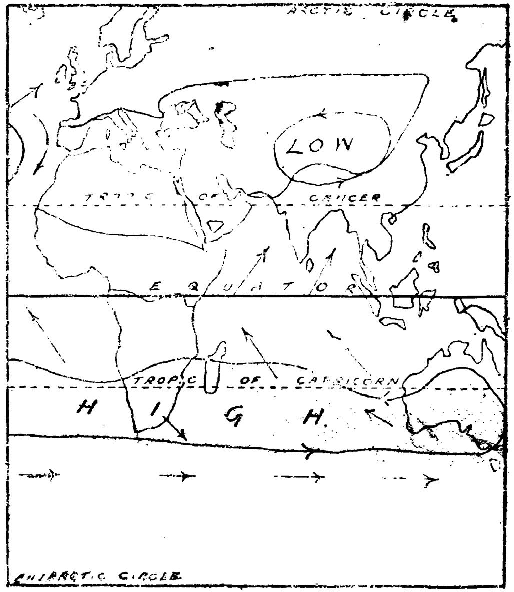

FIG. 64.—JULY ISOBARS REDUCED TO SEA LEVEL (Old World).

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rain. The high pressure area does not prevail over the Mediterranean region on account of the relatively high temperature of the Mediterranean Sea, and therefore this region has a good rainfall in the *winter months*.

Climatic Belts and Isotherms of the New World.

The northern portion of the world being turned away from the sun in *winter*, we find that about half of the northern temperate regions has a temperature below the freezing point. The sea is warmer than the land of corresponding latitudes, as may be seen by comparing the temperature of the Northern Pacific and Northern Atlantic with the temperature of Canada. The hottest parts of the Earth during our winter are of course in the Southern Hemisphere, especially in Queensland and Brazil. It will be noticed that the 60° isotherm runs through New Zealand in the southern Hemisphere, and California and Florida in the northern.

In our *summer* the above state of things is somewhat reversed. (See Fig. 66.) The portions below freezing point are found south of the Equator, and the 60° isotherm has retreated from Florida to Newfoundland. The hottest part of America is in Utah, and is crossed by the Tropic of Cancer.

Climatic Belts and Isotherms of the Old World.

In the northern *summer* the hottest belt is north of the Equator, and is found chiefly over the land. (See Fig. 68.) That the temperature of the atmosphere over the sea is much colder than that over the land in corresponding latitudes is apparent from the eastern portion of the Arabian Sea and the Bay of Bengal, which have a much lower temperature than the neighbouring land. Nearly the whole of Europe has a temperature between 60° and 80°, and no portion of Eurasia has a temperature below freezing point. The 60° isotherm crosses the central portion of the British Isles. It should be observed that South Africa and South Australia have a temperature below 60° in our summer.

In *winter* the moderating influence of the ocean, and especially of the Gulf Stream, is most marked in the north-west of Europe, where parts of Norway have a temperature much higher than regions in Russia and Asia that are many degrees farther south. (See Fig. 67.) The hottest *isothermal surface* in winter is south of the Equator, and is naturally over the land—Central Africa in Fig. 67—the specific heat of land being relatively much lower than that of the ocean.

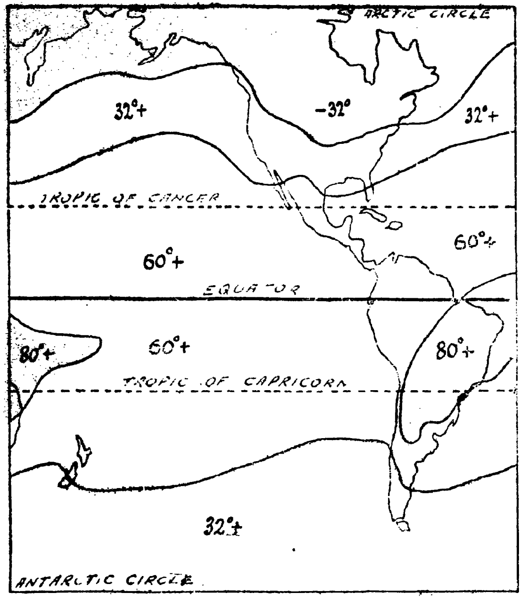

Fig. 65.—January Isotherms Reduced to Sea Level (New World).

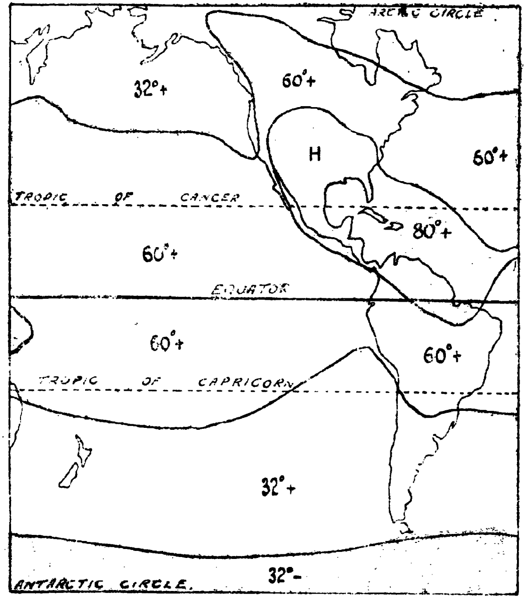

Fig. 66.—July Isotherms Reduced to Sea Level (New World).

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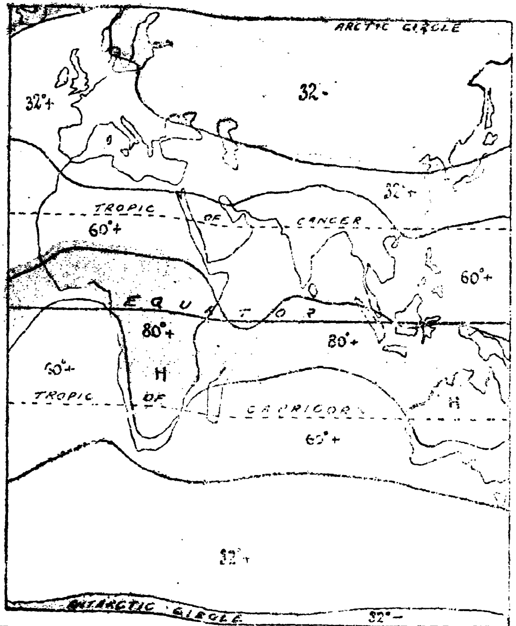

FIG 67.—JANUARY ISOTHERMS REDUCED TO SEA LEVEL (Old World).

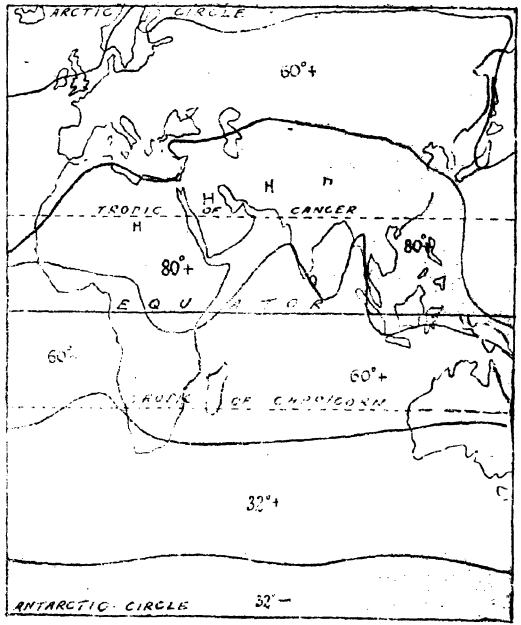

FIG. 68.—JULY ISOTHERMS REDUCED TO SEA LEVEL (Old World).

[To face p. 77.

Planetary Circulation of the Atmosphere.

The principal cause of winds is *difference in temperature*. The heated air of the Tropics rises, and colder winds from the Poles take its place. This general movement of cold air towards the Equator and of warm air towards the Poles is greatly modified by the presence of land-masses and also by the rotation of the earth. The Monsoons illustrate the effect of land-masses upon the direction of winds.

The air at the Equator partakes of the Earth's rotation and acquires an easterly velocity which is greater than the velocity of that part of the earth which is situated farther north or south. Consequently when the heated air from the Equator rises and moves either northwards or southwards, it *gains* upon the earth, and is converted into the South-West Winds of the Northern Hemisphere or the *Brave West Winds* of the Southern Hemisphere, when it returns again to the earth's surface. The belt where the Brave West Winds prevail is known as the *Roaring Forties*. (See Figs. 69 and 70.)

The cold air from the Poles on reaching the Tropics *loses* on the Earth, and is converted into the North-East Trades and the South-East Trades in the Northern and Southern Hemispheres respectively. The belt near the Equator where these Trade Winds meet is known as the *Doldrums*, and is characterised by heavy rains, calms, and thunderstorms. Somewhat similar calms occur along the Tropic of Cancer and the Tropic of Capricorn.

To the north and south of the Trades the winds generally blow from the south-west; *e.g.*, two out of every three winds reaching the shores of the British Isles are south-west winds. These winds are known as **Anti-trades.** The Trades and Anti-trades are most constant when blowing over the great oceans, but become irregular when they come in contact with land masses.

***Monsoons.**—The monsoons are periodical winds which prevail* in the Indian Ocean, blowing from the south-west during our summer months (April to October), and in the opposite direction during the winter. The south-west monsoons are moisture-laden, and cause the wet season in India. They blow in consequence of the sun being north of the Equator during the summer months, the hot air of the north rising and the cold air of the monsoons coming in to take its place. The north-east monsoons, coming from Central Asia, are consequently dry.

The **Sirocco** is a hot wind which blows from North Africa to Sicily and South Italy. It is supposed to be the simûm modified by its passage across the Mediterranean.

The **Simûm** (or *Simoom*, or *Simoon*) is a scorching wind which blows in countries bordering the deserts of Asia and Africa. It often carries with it clouds of sand. In Turkey it is known as the **Samiel.**

The **Harmattan** is a simûm which blows from the interior of Africa towards the Atlantic Ocean during the winter months. It blows for two or three days at a time.

The **Solano** is a hot south-east wind which blows in Spain.

The **Khamsin** is a hot southerly wind which blows in Egypt for a period of about fifty days.

The **Föhn** is a warm wind which blows in Switzerland.

The **Mistral** is a cold north-west wind which blows in southern France during winter.

Other cold winds are the **Bora** of the Alps, the **Etesian** winds of North Africa, the **Levanter** of the Mediterranean, and the **Puna** of Peru.

Land and Sea Breezes.—Along our shores in comparatively calm weather there is a tendency for a land breeze, *i.e.*, one blowing seawards, to prevail during the night, and for a sea breeze, *i.e.*, one blowing landwards, during the day. This alternation is due to the sea being warmer than the land during the night, and colder during the day. At night the warm air in contact with the surface of the ocean rises, and the colder and heavier air from the land takes its place. During the day this condition of things is reversed.

A somewhat similar effect is noticeable in the direction of summer and winter winds. There is a tendency for winds to blow towards the land in summer, and the summer rainfall is consequently heavier in such cases than the winter rainfall.

THE SEA.

Distribution.—The area of the water surface of the world is three times greater than that of the land surface. England has an area of fifty thousand square miles, and if we compare the total water surface of the world with the area of England, we find that it is three thousand times greater. This water surface is divided into five oceans.

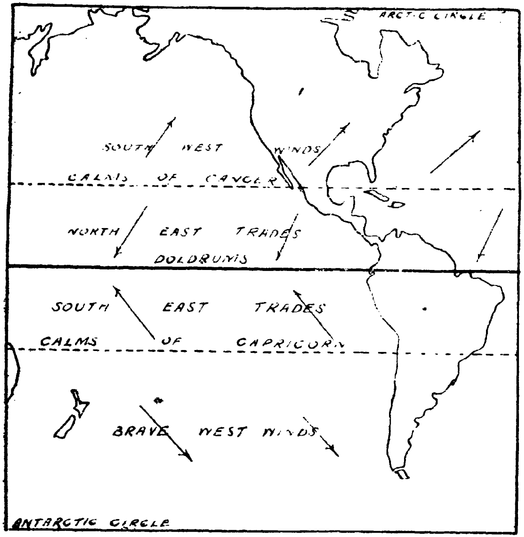

FIG. 69.—PREVAILING WINDS (New World).

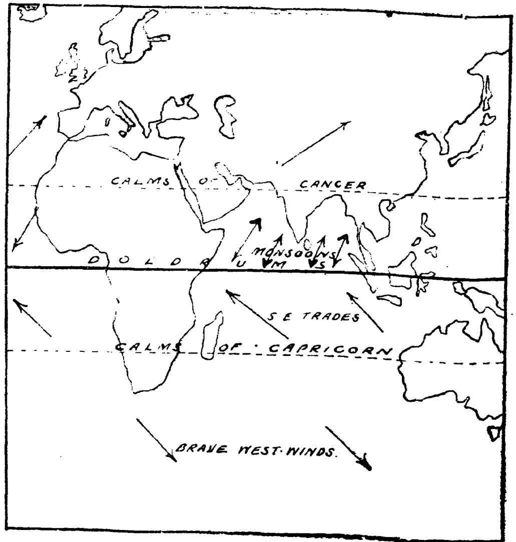

FIG. 70.—PREVAILING WINDS (Old World).

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Ocean Depths.

Approximate form, size, and depth of oceans:—

Ocean.	Form.	Size.	Average Depth.	Maximum Depth
Pacific ..	.. Semi-elliptical ..	6 times Africa ..	3 miles ..	5 miles
Atlantic	.. S-shaped ..	.. twice ,, ..	$2\frac{1}{2}$,, ..	$4\frac{1}{2}$,,
Indian ..	.. Semi-elliptical ..	twice ,, ..	2 ,, ..	4 ,,
Antarctic	.. Circular ..	.. equal to ,, ..	shallow..	unknown
Arctic ..	.. ,, ..	.. half ,, ..	,, ..	,,

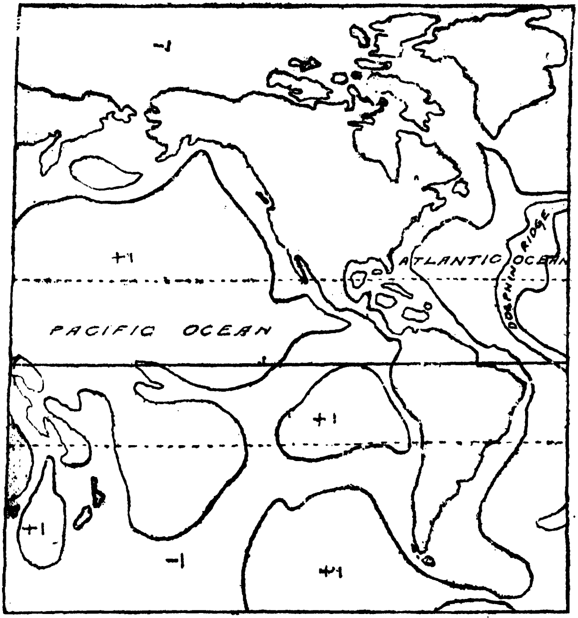


Fig. 71.—Ocean Depths.

+1 means more than one mile. −1, less than one mile.

From a glance at the accompanying maps of the oceans (Figs. 71, 72) it is evident that the shallowest parts are near the great continents, and form shelves, called *continental shelves.* The British Isles, for example, are on the continental shelf of Europe which extends to a distance of 200 miles to the west of Ireland, when the sea-floor suddenly sinks to a depth of many thousands of feet (see page 91).

The average depth of the ocean is much greater than the average height of the land. If the sea-level *fell one mile* (roughly 1,000 fathoms), comparatively little would be added to the *habitable* land area, but if it *rose one mile*, all the land, excepting the mountainous districts, would be submerged.

The Pacific and Atlantic are the deepest oceans, the greatest depths in these oceans hitherto discovered being $5\frac{3}{4}$ miles in the Pacific near the Friendly Islands, and $4\frac{1}{2}$ miles in the Atlantic near St. Thomas, in the West Indies.

The greatest oceanic depth, that of $5\frac{3}{4}$ miles, roughly corresponds to the height of the world's highest mountain peak, that of Everest, $5\frac{1}{2}$ miles.

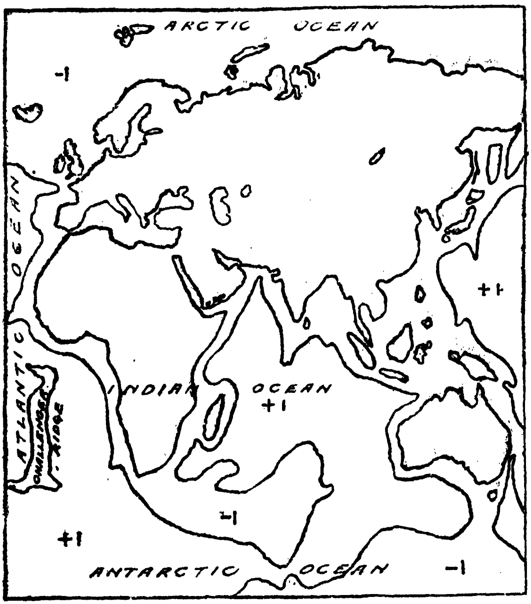


FIG. 72.—OCEAN DEPTHS.

Oceanic Movements.—The chief movements of the ocean are those connected with waves, drift and stream currents, and tides,

Waves.—Waves are the upward and downward movement of water, and are usually produced by the wind. The water particles of the wave remain above the same portion of the sea floor, but the *form* of the wave travels onwards. In great storms waves sometimes attain the height of 40 feet from trough to crest. The sea beach interferes with the free movement of a wave; the base is held back, and the upper part *breaks* in consequence. At times the force of these breakers is enormous. Their effects are practically confined to that part of the coast that lies between high and low tide.

Cliff Formation.—The cliffs that are deeply jointed, readily yield to the action of the waves, which are assisted in their work of disintegration by the sand they carry forward. The form that the coast ultimately assumes under the action of waves depends largely upon its structure. If the cliffs are composed of homogeneous materials, there is a tendency for the coast to be worn away *uniformly*, but if it is composed of materials of varying degrees of resistibility, the softer parts are rapidly washed away, while the harder parts remain as capes, headlands, or islands. A great deal also depends upon stratification.

A sea shore of *horizontally stratified* rocks forms *perpendicular* cliffs, because the waves break down such rocks along their jointed surfaces, which usually run at right angles to their planes of bedding. In the diagram, AB, CD, etc., represent the bedding planes or lines of stratification; EF, GH, etc., the joints at right angles to these planes. The waves undermine the cliffs, which ultimately fall along the joint EF, and then along the joint GH, thus invariably leaving a perpendicular cliff facing seawards.

If the strata dip seawards, overhanging cliffs will result. This may easily be seen from diagram, where F1, F2, F3 will be successively exposed as undermining continues; *aa*, *bb*, *cc* are the lines of bedding.

If the strata dip landwards, sloping cliffs are formed. In this case the cliffs along C1, C2, C3, etc., are exposed as the rock masses are undermined and washed away.

Drift Currents. These are movements of the surface water of the ocean occasioned by the wind, and frequently change their direction and rate of flow.

Stream Currents are streams in the ocean, and are caused by inequalities in temperature, the rotation of the Earth's axis, and the action of prevailing winds. They are often considerably

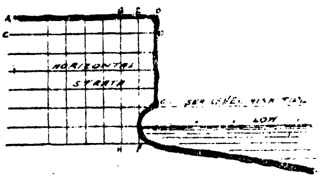


FIG. 73.
PERPENDICULAR CLIFFS.

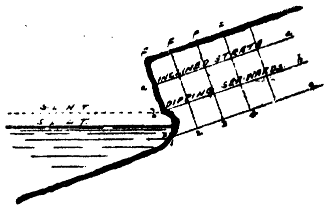


FIG. 74.
OVERHANGING CLIFFS.

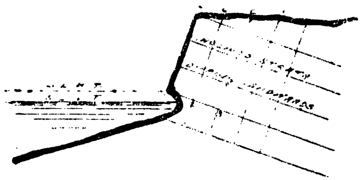


FIG. 75. SLOPING CLIFFS.

warmer or colder than the surrounding ocean, and are usually deep. In the following description of the various oceans the chief currents are enumerated.

The **ARCTIC OCEAN.**—The Arctic Ocean is the ocean which surrounds the North Pole. It is almost entirely enclosed by the shores of Europe, Asia, and North America. The **Behring Strait** connects it with the Pacific, while **Davis Strait,** and a wide passage between Greenland and Norway, lead into the Atlantic. The Arctic Ocean, being covered with ice for the most part, is of little commercial value, even the **whale** and **sea** fisheries being less important than formerly. The non-tabular character of the Arctic icebergs seems to indicate that this ocean extends to the North Pole. The principal islands are **Greenland,** the

North American Archipelago, Nova Zembla, Spitzbergen, and **Franz Joseph Land.** The principal openings are **Baffin Bay, Barents Sea, White Sea** (the most important), and **Kara Sea.**

FIG. 76.—THE ARCTIC OCEAN.

From the Arctic flows a Polar current, the **Arctic Current,** which washes the coast of Labrador, and meets the Gulf Stream near Newfoundland, where fogs are prevalent.

The **ANTARCTIC OCEAN.**—This ocean, situated within the Antarctic Circle, is of doubtful extent. It is not known how much land surrounds the South Pole, though the presence of flat-topped icebergs suggests the existence of a fair-sized continent. The northern portion is sometimes called the **Southern Ocean.** The Antarctic Ocean is of little or no commercial value. It is deeper and more stormy than the Arctic, and there being no land suitable for settlement, it is very seldom visited. Recently there has been great activity in the exploration of the Antarctic, and expeditions sent out by England, Scotland, Germany, Sweden, and France have added largely to our knowledge of it. The fringe of what may ultimately prove to be a large continent has been discovered; **Victoria Land, Graham Land, Oscar II. Land, Louis Philippe Land, King Edward VII. Land,** and **Knox Land** being some of the names already applied to it. The most famous island is **Erebus and Terror Island,** discovered by Ross, and which contains the active volcano of *Mount Erebus.* A remarkable feature of this ocean is the *Great Ice Barrier,* a precipitous wall of ice hundreds of miles in length, which is supposed to be the edge of an enormous ice-sheet formed by the glaciers of the Antarctic Continent. The only important animals are *seals, whales,* and *penguins.*

The **Antarctic Drift Current** flows from this ocean towards the shores of Chile, while another current flows towards Cape Colony.

The **ATLANTIC OCEAN.**—The Atlantic Ocean is commercially the most important ocean in the world. It extends from the Arctic Ocean in the north to the Antarctic Ocean in the south, and is enclosed on the east and west by the continents of the Old and New World respectively. The longest rivers of Europe, Africa, and America flow into it.

The principal seas and openings are **Hudson Bay,** the **Caribbean Sea,** the **Gulf of Mexico,** the **Gulf of Guinea,** the **Bay of Biscay,** and the inland seas of Europe.

It contains some of the most important islands in the world, namely the **British Isles,** the **West Indies,** the **Madeiras,** the **Canaries,** the **Azores, Iceland, Newfoundland,** and many others.

The *currents of the Atlantic* are well defined, and comprise the following:—

1. The **Gulf Stream** flows out of the Gulf of Mexico (hence its name), by way of the Strait of Florida, then continues in a north-easterly direction off the shores of the United States and Newfoundland, and finally crosses the Atlantic to wash the western coast of Europe. Its rate of velocity when flowing through the Strait of Florida is about 65 miles a day.
2. The **North African and Guinea Current** originates near the Azores, and flows generally southwards off the coast of North-West Africa, sweeping round the Gulf of Guinea.
8. The **South Equatorial Current** flows from the Cape of Good Hope, off the shores of South-West Africa, and ther

crosses the Atlantic, where it strikes the coast of Brazil near Cape San Roque. There it divides into two branches, one flowing southwards under the name of the *Brazil Current*, and the other flowing northwards into the Gulf of Mexico, from which it issues as the *Gulf Stream.*

4. The **Cape Horn Current** is a continuation of the Antarctic Drift Current, and flows off Cape Horn, towards the Cape of Good Hope.
5. The **Brazil Current** is the southern branch of the Equatorial Current off the shores of Brazil.
6. The **Labrador Current** flows from Davis Strait, off the coast of Labrador, and then between the Gulf Stream and the shores of Newfoundland and the United States.

To the east of Florida, in mid-Atlantic, is a portion of the ocean that is remarkably free from currents, known as the **Sargasso Sea.** This sea receives its name from the seaweed (*sargassum*) which abounds there. There is a *Lesser Sargasso Sea* in the middle of the South Atlantic Ocean, in which there is no seaweed of this kind.

Between the eastern and western portions of the Atlantic is a submarine plateau which has been of the greatest use in the laying of the Atlantic telegraph cables between Ireland and Newfoundland. Off Porto Rico, in the West Indies, the greatest depth in the Atlantic has been obtained, namely, 27,000 feet. The chief fish caught are *cod*, *herring*, and *mackerel*. *Oysters* are obtained in the Bay of Biscay.

The **PACIFIC OCEAN.**—The Pacific is the name given to the great expanse of water which stretches from America to Asia and Australia. It was discovered near the commencement of the sixteenth century, and Magellan, who gave the name **Pacific** to the ocean on account of its peaceful appearance, sailed across it in 1521.

The Pacific is now becoming a most important commercial highway. There are comparatively few indentations, the chief being the **Behring Sea,** the **Sea of Okhotsk,** the **Sea of Japan,** the **Yellow Sea,** and the **South China Sea,** all on the Asiatic side.

The principal island groups are the **Japanese Islands,** the **East Indies,** and the numerous coral and volcanic islands of Oceania.

A noteworthy feature of the bounding shores of the Pacific is their volcanic character, there being a line of weakness both on the Asiatic and American side.

The only long rivers entering the Pacific are those that flow from China, the most important being the **Yang-tse-Kiang** and the **Hoangho.**

The **Great Equatorial Current** is the best known Pacific current. It flows northwards under the name of the **Peruvian Current** until it reaches the equator, when it bends westward and crosses the Pacific until it arrives at the East Indies. Here it divides into two branches, one flowing northwards alongside Japan, under the name of the **Kuro Siwa,** the other continuing its easterly direction through the straits between the numerous islands of the East Indian Archipelago.

The **INDIAN OCEAN.**—The Indian Ocean is almost entirely

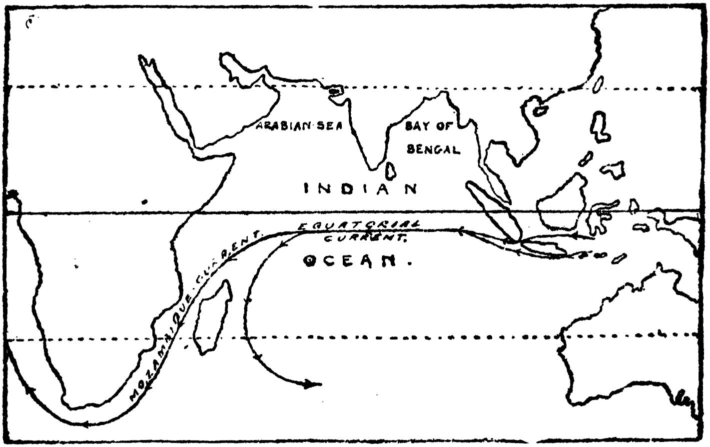


FIG. 78.—INDIAN OCEAN.

enclosed on three sides by Africa, Southern Asia, and Australia. There is no definite natural limit in the south, where the 40th parallel of latitude is generally considered to be the boundary line.

The largest openings are the **Red Sea,** the **Arabian Sea,** the **Bay of Bengal,** and the **Timor Sea.**

The largest islands are **Madagascar, Ceylon, Mauritius, Sokotra,** and **Nicobars, Laccadives, Andaman,** and several smaller islands.

The *currents of the Indian Ocean* are not nearly so constant as those of the other **oceans**, being influenced by the **Monsoons**, which are changeable winds. The best known currents are:—

1. The **Equatorial Current**, which flows from the East Indies towards Madagascar, where it then divides.
2. The **Mozambique Current**, which is a branch of the Great Equatorial Current, and flows southwards between Madagascar and the mainland of Africa.
3. The **Agulhas Current**, which is a continuation of the Equatorial Current, and flows eastwards near the coast of Natal and Cape Colony.

The most important rivers flowing into this ocean are those from Southern Asia and East Africa, the principal being the **Ganges, Brahmaputra, Indus, Irawadi, Zambesi,** and **Limpopo.**

The discovery of the sea route to India round the Cape of Good Hope in 1497, the finding of the Australian goldfields in 1851, and the completion of the Suez Canal in 1868, were important events in the development of the trade across the Indian Ocean.

TIDES.—A description of the formation of tides will be found on pages 27-30.

The tidal wave is best observed in the Pacific, the great width of which interferes least with its passage westward. Its movement in the other oceans is interfered with considerably by their narrowness and the neighbouring land masses, with the result that places in the same longitude are not necessarily reached by the tidal wave at the same time. At the British seaports, for example, the time of high tide varies greatly.

When the tidal wave reaches the shores of the British Isles, it proceeds in three different directions:—

1. Round the northern shores of Ireland and Scotland into the Irish Sea and North Sea respectively;
2. Through the St. George's Channel into the Irish Sea;
3. Through the English Channel into the North Sea, where it meets (1) at the mouth of the Thames.

When the tidal wave flows into narrowing estuaries, the tide is comparatively high. At Cardiff in the Bristol Channel the spring-tide rises 42 feet, while at the head of the Bay of Fundy it reaches 70 feet, and this is the highest tide in the world.

The Tides of the Mediterranean have a height varying from a few inches to six feet. The slight difference between high and

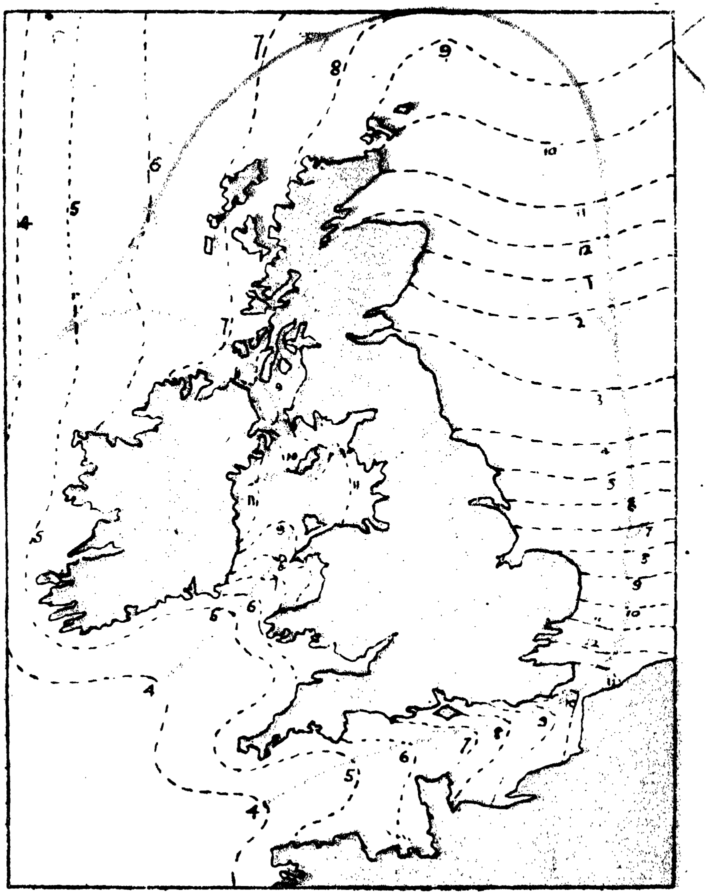
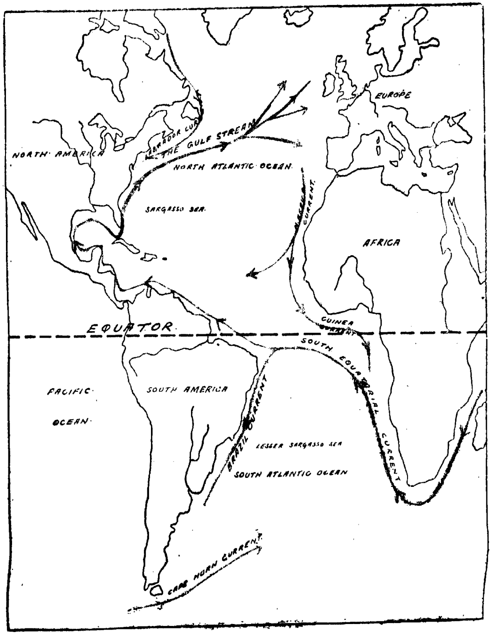
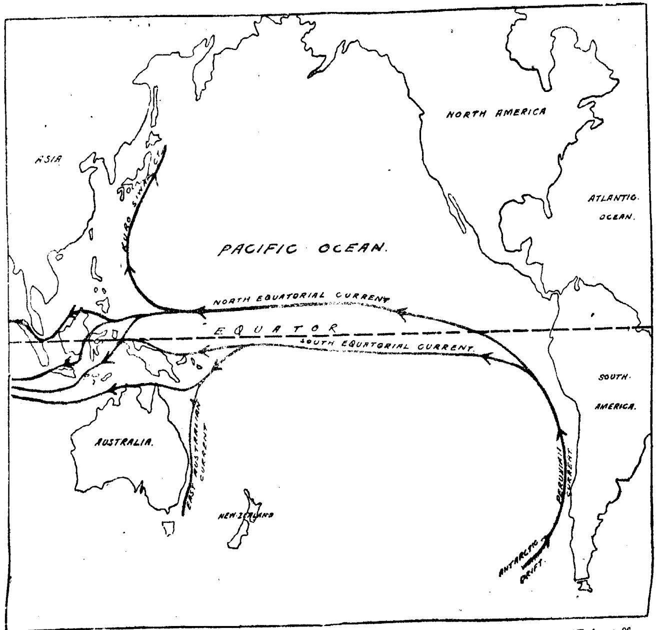


FIG. 79.—THE BRITISH ISLES CO-TIDAL LINES.

low tide in the Mediterranean generally, is due to the narrow



CURRENTS OF ATLANTIC OCEAN.



CURRENTS OF PACIFIC OCEAN.

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entrance into the Atlantic, which counteracts the full effect of the *oceanic* tidal wave.

Temperature of Sea Water.—A study of the isotherms on pages 75 and 77 reveals the fact that the surface temperatures of the sea vary considerably in different parts of the world, being below freezing point (salt water freezes at 28°F) in the arctic regions, and about 90° near the equator. These temperatures are often affected by warm or cold currents of water or air, and also by the neighbourhood of land masses.

The temperature of the sea is more uniform than that of the land on account of its great specific heat, *i.e.*, the great amount of heat required to increase its temperature.

Below the surface of the ocean the temperature falls rapidly, and the deepest parts of the oceans are always very cold, about 30°F. The rate of decrease in temperature is not uniform with the depth. For the first three hundred feet the temperature falls rapidly, diminishing about 30°. Beyond that depth the decrease is more gradual. Partially-enclosed seas have frequently a temperature different from that of the neighbouring ocean. This is sometimes due to a sub-marine shelf, which prevents the ice-cold water of the deep ocean outside from entering the warmer water of the partially-enclosed sea.

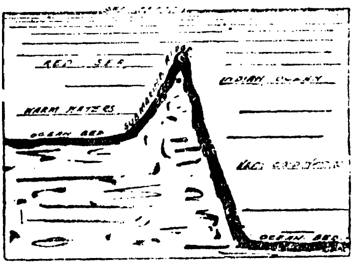


FIG. 80.
Submarine ridge prevents cold waters of the Indian Ocean from entering the Red Sea.

Composition of Sea Water.—The chief difference between sea water and fresh water is that the former contains salts in solution, especially common salt ($NaCl$) and magnesium chloride ($MgCl_2$), which make it bitter to the taste. Rivers carry these salts into the ocean, with the result that they are deposited during the process of evaporation, and there is a tendency for the ocean to become more and more saline. This salinity lowers its freezing point.

The following is a table of the salts usually found in sea water, which may be obtained by evaporation :—

PERCENTAGE OF SALTS.

Chloride of Sodium	77·8
Chloride of Magnesium	10·8
Sulphates of Magnesium, Calcium, and Potassium ..	10·8
Other Salts	·6

In sea water the dissolved salts form 3½% of the whole, and this percentage indicates the degree of salinity. There is very little silica or calcium carbonate (chalk) in sea water, and this is accounted for by the fact that minute marine organisms, such as radiolarians and foraminifers, form their shells from these substances.

Ocean Floor.—The relief of the ocean floor is represented, as in land, by difference in colouring, figures for depths, vertical sections, or by a combination of two or more of these. The ocean has an average depth of two miles, and its floor is characterised by plains, table-lands, and mountains, the peaks of

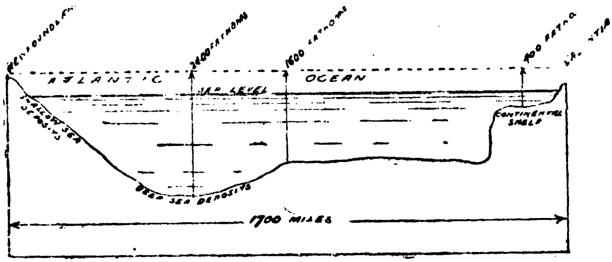


FIG. 81.
Section of Ocean Floor from Newfoundland to Ireland.

the latter often rising above the surface to form islands. When a section of an ocean is shown, the vertical scale of the diagram is usually exaggerated in order to give a graphic representation of the varying depths. In the accompanying diagram, which represents a section of the Atlantic Ocean from Newfoundland to Ireland, the vertical scale is seventy times greater than the horizontal scale.

Marine Deposits.—The sea floor is covered with various deposits, which may be classified as follows:—

(1) Shore deposits.
(2) Shallow sea deposits.
(3) Deep sea deposits.

The *shore deposits* are found between high water mark and a line which is a little distance below low water mark. They consist of *gravel*, *shingle*, and *coarse sand*, irregularly bedded, and showing evidence of cross currents in the finer material, which is nearest the sea. Organic remains are not plentiful, and the shells found are generally broken and rolled.

The *shallow sea deposits* extend from the limit of the shore deposits to a depth of about half-a-mile. This depth is found at varying distances from the shore, and may be sixty, or even two hundred, miles from the coast. If the sea deepens rapidly from the shore, the shore deposits soon cease, and the shallow sea deposits make their appearance, although the shore deposits may be carried a considerable distance out to sea by the strong current of a large river. The shallow sea deposits consist of *clay*, *fine sand*, and *mud*, derived from the neighbouring land. Organic remains are plentiful in the form of *ooze*, *coral rock*, *limestone*, and *chalk*. All these accumulations are spread over a wide area, and are regularly bedded. The most noteworthy of these deposits are the siliceous remains of diatoms (microscopic plants) and radiolarians and the calcareous shells of globigerina and other microscopic foraminifers.

Deep sea deposits are found at depths of half-a-mile or more, and contain practically no terrigenous substances, with the exception of volcanic matter. They consist of *red clay*, which is the most widely-distributed of all deep sea deposits, and of various *oozes*. The red clay is due to the chemical action of sea water upon pumice, ash, and other volcanic matter which has drifted out to sea or been ejected by sub-marine volcanoes. Its red colour is caused by the presence of the oxides of iron and manganese. The oozes are chiefly of organic origin, and are composed of globigerina, pteropods, diatoms, radiolarians, and other minute organisms.

The following is a picturesque description of the deposits in the ocean, by Dr. Alcock, of the Survey Ship "Investigator," who made a scientific exploration of the sea floor of the Bay of Bengal.

The World beneath the Waves.—"Of the world beneath the sea, and of its inhabitants, our ancestors—even our immediate ancestors—had little information and scant idea, and it was not until the middle of the nineteenth century, when submarine cables came to be talked about that our knowledge of the physical geography and natural history of the bed of the ocean began to approach the exact stage.

If we could for a moment run all the water out of one of the great ocean basins, and lay its bed bare, we should find ourselves in a land a good deal different from any to which we have been accustomed. Many of the main features we should, of course, recognise; we should find hills and table-lands, and plains and valleys, and we should see mountain-slopes rising, with little-varying degrees of steepness, towards the continents and islands that form the dry land. But what would astonish us would be their vastness, their simplicity, and their uniformity, in other words, their want of character, due to the fact that the natural agencies, which should add beauty of feature, are non-existent.

The dry land is the scene of an unceasing tumult of plastic forces; sun and frost, rain and flood, glacier and torrent, wind and wave, are continually at work changing its appearance almost after the manner of a living spirit. But beneath the ocean none of these sculpturing forces are known. There there is little or no change in temperature, and no violent movement of water, consequently the landscape has no detail, and its style is vast, monotonous, and unvaried. For instance, if we could walk straight across the Bay of Bengal (which, though we call it a bay, is really a great inlet of the ocean) from Madras to the Andamans, we should for the first 10 or 11 miles traverse a decline so imperceptible as to seem almost level; we should then for another 30 miles descend a sudden and very steep slope, until, at about 40 miles from shore, we should reach level ground at a depth of about 11,000 feet below the sea-line. Once there, we should walk for more than 600 miles over a plain as flat as a tea-tray, until we came to a corresponding ascent up to the Andaman shore.

In our journey across our supposed dried-up ocean bed, though we should have no scenery to admire, there would be much to interest us in the ground beneath our feet. We should, of course, find numerous remains—shells and skeletons—of all sorts of sea animals; but, for reasons to be presently given, we should, when we had made our first descent of 600 feet, see nothing in the shape of sea-weed; however, it is to the ground itself that we must turn our attention.

After we had left behind us the *rocks*, and *reefs*, and *shingle*, and *sand* of the shore, we should come to *mud;* it would most likely be of a dark bluish colour, and it probably would not smell very sweet. This mud is the sediment that has been brought down by the rivers, and is therefore derived from the land.

In certain places where no rivers of any size flow into the sea, as for instance, in the neighbourhood of coral islands, we should probably find a greyish or whitish mud, made up chiefly of coral detritus. But in the neighbourhood of most of the continents we should find—as all round the boundaries of the Bay of Bengal—a fringe or steep "shoot" of dark-coloured mud, and the breadth of this fringe would vary, according to the number and volume of rivers in the vicinity, from 60 to 300 miles.

To resume our imaginary journey from Madras to the Andamans. At a distance of about 50 miles from shore the mud would begin to change; it would gradually become more and more gritty and lighter in colour, until we should at last find ourselves walking on ground something like dirty chalk. This is *Globigerina-ooze* that forms such a large part of the bed of the ocean in tropical and temperate regions.

Globigerina-ooze, so-called from the species most constantly and most abundantly found in it, is, for the most part, made up of dead shells of the minute and lowly animalcules known as *Foraminifera.* They belong to the very lowest class of the animal kingdom, and they swarm throughout the warmer seas; and as they die, their shells, which usually, but not always, are made of carbonate of lime, fall to the bottom like, as has been aptly said, a perpetual shower of rain, and there accumulate to form vast beds of sediment not very different from the familiar chalk of south-eastern England. The shower of shells may be, and often is, also falling where the blue mud is being deposited, but there it is quite lost in the infinitely more voluminous mass of river-borne sediment; so that it is only at a considerable distance from land, and when all the river-borne material has settled, that we get pure Globigerina-ooze.

But Foraminifera are not the only animals whose remains form, or help to form, oceanic deposits. The surface waters of the open sea swarm with delicate shell-secreting animals of other and far higher kind. Conspicuous among these, in certain latitudes, are the sea-butterflies or pteripoda, small mollusks not distantly related to the cuttle-fishes, whose shells resemble little caps and purses of the finest glass. When they die, their shells too fall to the bottom, and sometimes in numbers sufficient to overwhelm the foraminifera shells, and to turn the Globigerina-ooze into *Pteropod-ooze.*

In our imaginary journey across the Bay of Bengal, we should meet with nothing but the deposits mentioned above. We must, therefore, go outside the comparatively lower limits of the Bay of Bengal, whose greatest depths do not much exceed 2,000 fathoms, if we would make our idea of the ocean floor complete.

And first we must take note of the fact that the surface waters of the ocean support multitudes of microscopic animalcules, nearly related to the Foraminifera, but differing from the latter in having shells of silica, or what we may without any serious misrepresentation call flint. These hard-shelled animalcules are called Radiolaria, and although they are not nearly so abundant as the comparatively soft-shelled Foraminifera, yet some of their shells are almost always present in Globigerina and other ooze, and in certain corners of the ocean they are sufficiently numerous to form an almost pure siliceous deposit known as *Radiolarian-ooze.* For reasons that will presently appear Radiolarian-ooze is met with only at great depths.

But the animalcules, and especially the Foraminifera, whose mortal remains collect to form these calcareous and siliceous oozes, are only found in profusion in oceanic waters of a certain necessary warmth. In the colder waters of the higher latitudes they are not numerous enough to give a denominating character to the sediment that subsides to the bottom of the open ocean.

Now, amid the teeming life of the ocean there are to be found in abundance certain microscopic plants of the lowliest kind. We must call them plants because they belong to the vegetable kingdom, but they are not in the least like any plants that are visible to the naked eye. Not only do they swarm throughout the sea, but they are also universally diffused in fresh waters, and, in short, wherever there is moisture. These humble microscopic "plants" are known as Diatoms, and in the scheme of nature they stand and wait at the bottom of the class to which the seaweeds and moulds belong, being in fact rather nearly related to the Bacteria which have nowadays become so popularly unpopular. Many of them are enclosed in an excessively fine shell of the nearly indestructible substance silica, like the Radiolaria.

When the oceanic diatoms die, their shells, of course, sink like an invisible dust to the bottom; and although in warm latitudes these are lost amid the downpour of Foraminifera, yet in colder regions, where surface Foraminifera are few, the diatoms hold their own, and at length may collect as a pale siliceous deposit known as *Diatom-ooze.* But neither Diatom nor Radiolarian-ooze, nor yet, abundant as it is, Globigerina-ooze, cover all, or nearly all, of the floor of the open ocean. Far more extensive than all these oozes combined is a deposit called by its discoverers (in the Challenger) *Red Clay*, which, when examined under the microscope, is found to consist in large part of altered volcanic materials. This red clay is found pure only at the very greatest depths. Mixed up with it, of course, are certain indestructible remains of marine animals, spicules of siliceous sponges, sharks' teeth, ear-bones of whales, etc.; such are also to be found in all marine deposits; but a great part of it is derived from the minute particles of the volcanic and cosmic dust that floats invisible in the atmosphere. Though this dust is co-extensive with the atmosphere itself; though probably it exists everywhere, and is falling unseen everywhere, yet everywhere except in the solitudes of the ocean it is lost amid other grosser matter, and it is only in the remote abysses of the ocean that it falls unmixed with other material, and in the fulness of time aids in forming a deposit of appreciable thickness. The question will at once occur, how can such a pure deposit of volcanic (and cosmic) origin ever be formed? We can understand that the sediment brought down by the rivers must gradually subside before it is carried very far from land; but are not the shells of Foraminifera, and Pteripods, and Radiolaria, and Diatoms, always being showered down? The answer is that these shells are, indeed, falling everywhere, and that although in water that is not too deep they reach the bottom safely and cover each other up, yet in the abysses of the ocean they are either dissolved or otherwise destroyed before they get to the bottom. The Pteropod and Foraminifera shells, which consist of carbonate of lime, are dissolved by the sea-water, and may disappear completely, but even the resistent Radiolarian and Diatom shells, though they are not completely dissolved, yet at last get broken and chemically altered, until finally there is little left to fall in the great depths of the ocean but the settling volcanic dust."

LAND.

Divisions of Land.—We may divide the land surface of the world into Lowlands and Highlands according to its height. *Lowlands* include all the land less than six hundred feet in height, while all the land above that height receives the name of *Highlands*. Some geographers consider that the name of *Uplands* should be applied to land between 600 and 2,000 feet in height, and that the term Highlands should be restricted to land that is upwards of 2,000 feet in height. In the following pages the word *Highlands* is used in the former sense, that is, for land above 600 feet high.

From the accompanying map it will be observed that the great European Plain and the Plain of Northern Siberia, both of which are situated in Eurasia, are the most extensive Lowlands in the world. North-East Canada, the Lower Mississippi Valley, the Selvas, and the Pampas are the most important Lowlands of America. Speaking generally, the land near the sea coasts, and that forming the "plain tracks" of large rivers, are usually of a lowland character. Africa, Central and Southern Asia, Central Australia, and Western America are chiefly highland.

Plains are not necessarily of a lowland nature. A plain is a flat or slightly sloping stretch of country. It may be below sea level, when it is termed a *sunk plain*. If it is between sea level and a height of 600 feet it is known as a *lowland plain*. Above 600 feet it is called a *highland plain*. Lowland plains are usually of sedimentary origin, and frequently contain the lower courses and deltas of rivers.

Tablelands.—A Highland Plain is often called a Tableland or Plateau. The abrupt sides of a tableland are termed *scarps*, although this term may be applied to steep slopes of any kind, *e.g.*, sea cliffs. The effect of scarps in depriving winds of their moisture and in rendering the tablelands arid is noticeable in the case of Spain. Some tablelands are composed of horizontal strata which may be either of sedimentary or of volcanic origin. They

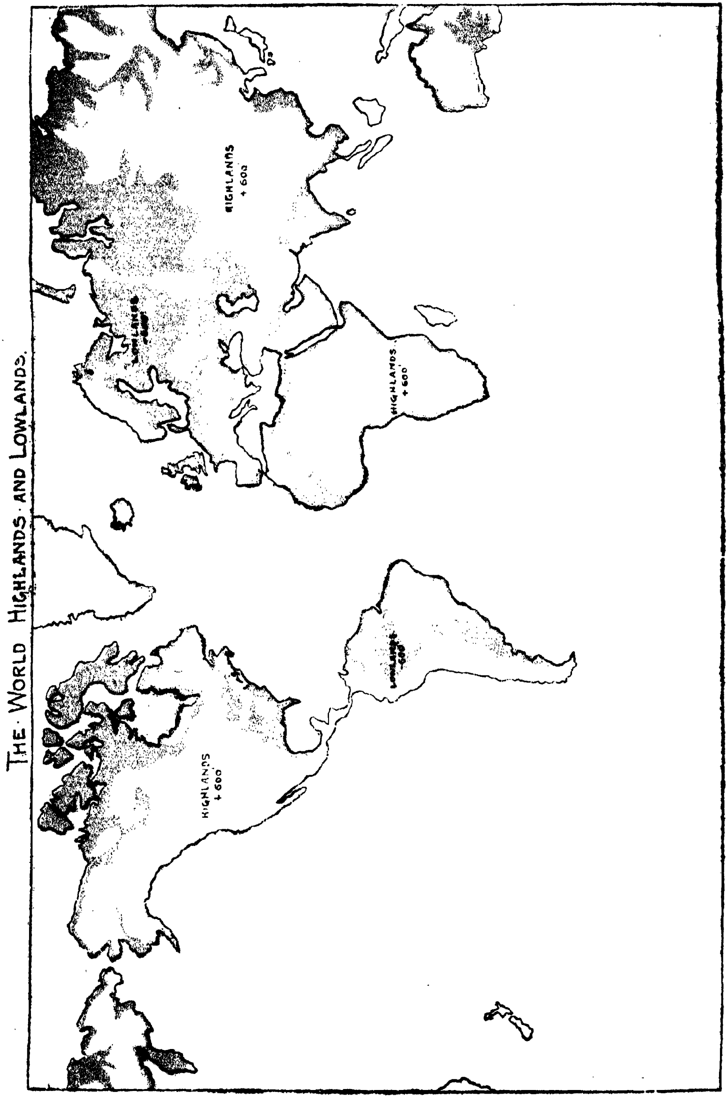


FIG. 82.

[To face p. 99.

may have been deposited, for example, in a lake, or poured out of some volcano in the form of lava. Such tablelands are called *tablelands of accumulation*, and the slope of division between such tablelands and the surrounding country is called an **escarpment.** An escarpment, therefore, indicates the outcrop of a formation of rocks of a different character than those of the lower land in the immediate vicinity.

Other tablelands have been formed from formerly lofty and irregular rocks which have been gradually worn down to a uniform level by rain and other agents of denudation, and are called *tablelands of denudation* in consequence.

Hollows.—When the higher lands enclose, or partially enclose, a country, a *hollow*, at the lowest level of which lakes are usually found, is formed.

Mountains.—The term *mountain* is necessarily vague. It is given to certain land-masses which rise more than 2,000 feet above sea level. All land-masses above 2,000 feet, however, are not termed mountains, as they may be no considerable height above the surrounding country. The Tibetan tableland, for instance, is upwards of 15,000 feet in height, and has many peaks that rise a few feet above its average level, but it would be obviously inappropriate to describe such peaks as mountains. A typical mountain chain consists of strata that have been crumpled

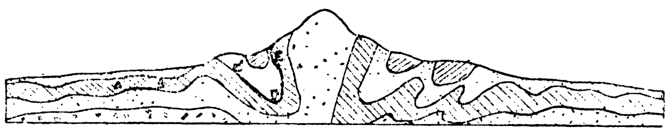


FIG. 83.—ELEVATION OF MOUNTAIN CHAIN.
AB=Anticline. CDE=Syncline.

and folded by lateral pressure into a series of *synclines* and *anticlines.* This lateral pressure is frequently due to the cooling and consequent unequal shrinking of a portion of the earth's crust. A vertical section at right angles to the direction of such a mountain chain might be drawn as in the diagram above. The surface of the synclines and anticlines is afterwards considerably modified by denudation, that is by the action of rain, rivers, snow, frost, and ice, and under the influence of this action the surface, if the rocks are uniform in composition, tends to become uniform in slope. If the rocks are not uniform or homogeneous, the harder parts will stand above the more easily eroded masses. These harder parts may be so large and lofty that they may constitute *mountains of denudation*, and it is likely that the Cotswolds, the North and South Downs, and the Pennines are the escarpments of mountains of denudation.

Anticlines are weakest at their summit, and are apt to be broken down into wide valleys by epigene agents. For example, the anticline ABC is apt to be disintegrated and washed away, and such a valley as ADC would take its place. (See diagram).

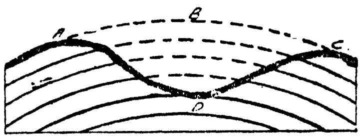


FIG. 84.
Formation of Valley from Anticline.

Watersheds.—A watershed or water parting is the highest ridge along which two divergent slopes meet.

Drainage Areas.—The drainage area of a river is the land drained by a river and all its tributaries, and lies between its outer watersheds. There are many types of such drainage areas.

(1) *Horizontally stratified rocks with little rainfall.*—In order to understand the effect of river action in a drainage area of this kind it is necessary to bear in mind the two processes of *erosion* and *deposition*. The course of most rivers consists of a *mountain track*, which includes the source and the steepest portion of its course; a *valley track*, which is the middle part of its course; and a *plain track* which succeeds the valley track, and includes the mouth of the river. In the mountain or steepest track the work of erosion is greater than that of deposition. In the valley track the amount of erosion is roughly equal to the amount of deposition. In the plain track deposition exceeds erosion, and is so great at times that extensive alluvial plains and large deltas are formed of the material brought down by the river. In an area of little rainfall and of horizontal rocks a river tends to form perpendicular banks of considerable height as it cuts its way to

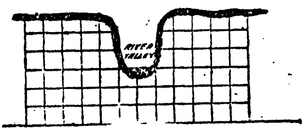


FIG. 85.
Drainage Area of Horizontal Strata.

greater depths. It has few tributaries, and the scanty rainfall is insufficient to wash down the surface material from the banks, which give way along the joints at right angles to the planes of bedding, and thus retain their perpendicular character. A striking example of this is manifest in the Grand Cañon of the Colorado River, which is 400 miles long, and has perpendicular sides between 3,000 and 6,000 feet high.

(2) *Horizontal rocks with heavy rainfall.*—In such an area the streams run between perpendicular banks which are usually much wider apart than in a region of scanty rainfall. The volume of water and the quantity of material transported and deposited is much greater.

(3) *Soft and Hard Rocks alternately.*—A river flowing through a drainage area, composed of rocks which vary considerably in their degree of resistibility, is characterised by alternate expansions

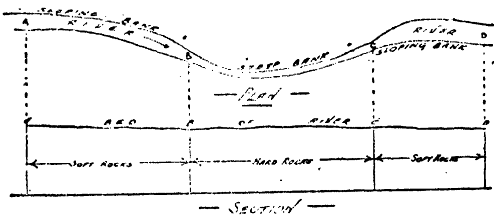


FIG. 86.—HARD AND SOFT ROCKS.

and contractions in its course, the hard and soft rocks forming narrow and wide valleys respectively, as illustrated in diagram.

S ft and Hard Rocks at different horizontal levels.—This

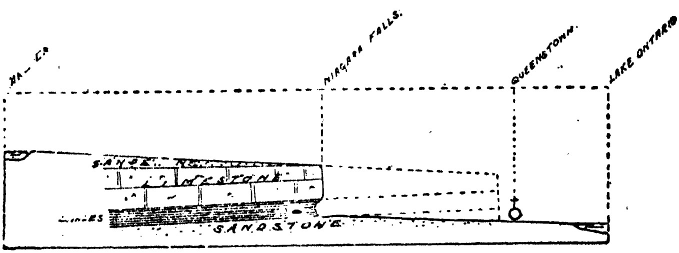


FIG. 87.—NIAGARA FALLS.

arrangement often results in the formation of waterfalls and cataracts. If a river flows over strata composed of hard rocks that superimpose softer material, the gradual erosion of the latter tends to undermine the harder rocks, with the result that they break down, and a waterfall is formed. The Falls of Niagara afford an excellent example of this process. Between Lake Erie and Lake Ontario the bed of the river consists of sandstones, limestones, and shales, and the Falls occur where the limestones come to the surface. Below the limestones, however, are easily eroded shales, which on yielding, cause the harder rocks to fall into the stream below. The Falls are thus gradually cut back and are perceptibly retreating year by year.

(5) *Inclined Strata.*—When the rocks dip, the opposite banks of a river flowing across and through the rocks, vary considerably in slope. The rocks dipping towards the stream tend to slip

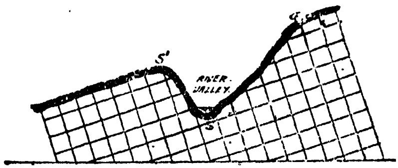


FIG. 88.—Drainage Area of Inclined Strata.
S'S=Steep Slope. GS=Gradual Slope.

downwards and to form a long and gradual slope, while the banks on the other side of the stream are usually short and steep.

Transportation of material by rivers.—The amount and composition of material carried in solution, or in suspension, depends upon the geological nature of the rocks constituting the drainage area. If the rocks are easily eroded, the amount of material carried is frequently enormous, especially in time of flood. Some of the African rivers contain as much sand as water. Rivers flowing over limestone regions, or over beds of calcium sulphate, dissolve large quantities of those substances, and their waters are said to be temporarily or permanently *hard*, while rivers flowing over igneous rocks carry very little material in solution, and the water is *soft* in consequence.

Rivers are thus important agents in changing the configuration of a country. Many physical features once attributed to volcanic action are now ascribed to the work of rivers carried on for a long period of time. Reference has already been made to *the chemical action of rivers in dissolving rock substances.* Their power to disintegrate and transport rocks by mechanical action results in the gradual removal of higher tracts of land to a lower level. The amount carried in suspension can be estimated by *filtration*, but the substances in solution can only be ascertained by *evaporation*.

It has been estimated that the Ganges transports seven thousand million cubic feet of sediment every year, and the effect of such transportation upon the physical features of the country can scarcely be over-estimated. This sediment often forms sand-bars or deltas at the mouths of rivers where the velocity of the current is least, especially if the outlet is not exposed to the full power of the ocean, *e.g.*, Nile, Mississippi, Po, and Rhone. The annual advancement of the delta of the Rhone is estimated at twenty yards.

Drainage areas of oceans.—The drainage area of an ocean is the land drained by the rivers which flow into that ocean. The longest slopes of most of the continents, for example, Europe, America, and Africa, are directed towards the Atlantic Ocean, which is consequently the largest drainage area, embracing 34% of the land surface of the world. One fifth of the Earth's surface has an *inland* drainage. The drainage areas of the Arctic, Indian, and Pacific Oceans are approximately equal, the total area drained into these oceans being half the land surface of the world.

LAKES.

The largest lakes in the world are:—

	Area.	Surface.
Caspian Sea ...	3½ times England	90 ft. below sea level.
Lake Superior ..	⅝ „ „	600 „ above „
Victoria Nyanza	more than half England	3300 „ „ „
Aral Sea	„ „ „	150 „ „ „
Lake Huron ...	less than half England	600 „ „ „

The Dead Sea is 1800ft. below sea level.

Salt-water lakes may be formed—

(1) By portions of the sea being cut off.

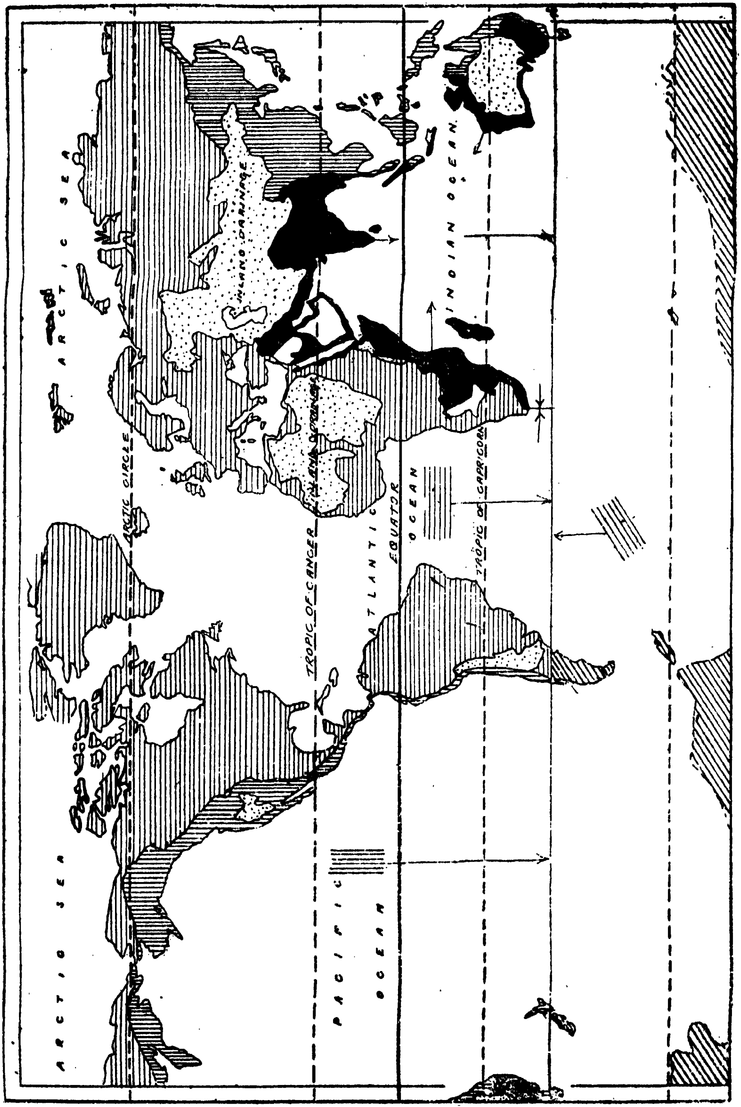


FIG. 89.—DRAINAGE AREAS OF OCEANS. [To face p. 105.

(2) By fresh-water lakes becoming more and more saline through excessive evaporation.

The Caspian and Aral Seas are lakes that were formerly connected with the Baltic, but have been cut off from that sea by the gradual elevation of the land. An evidence of this is the abundance of *marine* shells in the neighbourhood of these seas.

The salt lake of Utah was formerly a fresh-water lake, and was drained by rivers flowing into the Pacific. The *fresh-water* shells and raised beaches of the district are an evidence of the former existence of fresh-water conditions.

The Dead Sea was formerly drained by the river Jordan into the Red Sea, and its waters at that time were comparatively fresh.

Fresh-water Lakes have been formed in the craters of volcanoes, or in hollows produced in the following manner:—

(1) By local subsidence through the action of underground water.

(2) By a general subsidence of a large area due to the shrinking of the earth.

(3) By local landslips.

(4) By a gradual accumulation of sediment obstructing the outflow of a river.

(5) By the action of glaciers.

The action of glaciers accounts for the formation of the Lake of Geneva, Loch Lomond, and other lakes in the northern countries of the world. These countries were formerly subjected to the erosive action of many large glaciers that have now disappeared, owing to warmer conditions.

Lakes act as *filters* with respect to the rivers flowing into them. The Lake of Geneva, for example, checks the inflowing waters of the Rhone, causing the deposition of the material in suspension, and the Rhone ultimately flows out of the western extremity of the lake as a clear stream. The heavier material is, of course, deposited first, so that the *lacustrine deposits* exhibit a gradation from coarse to fine material, according to the lesser or greater distance from the shore.

GLACIERS.

Glaciers are rivers of ice, and are formed at high altitudes by the pressure of accumulated snow. This pressure causes the lower layers to pass into névé and ultimately into ice. Glaciers flow down the mountain valleys, eroding the rocks over which they pass and carrying the débris which falls upon them. This débris tends to collect at each side of the glacier to form *lateral* moraines. If two glaciers meet, the contiguous moraines unite to form a *medial* moraine. When the glacier melts, this morainic material is deposited as a *terminal* moraine, which consists chiefly of stones, more or less glacially striated. The average rate of flow of a glacier is about one foot per day. Should the glacier flow into the sea, portions are broken off to form icebergs, which float on the surface of the ocean, owing to the specific gravity of ice being less than that of water From an examination of moraines that are in the process of formation, it is evident that much morainic material exists in our own country, and the deposition of this is attributed to a previous age—the Great Ice Age—when glaciers extended as far south as the Thames. The morainic material in the British Isles consists of a tough unstratified clay, called Till or Boulder Clay, erratics brought from long distances, and striated stones.

Underground Water.

A considerable quantity of the rain that falls does not drain away along the surface of the ground, but sinks through the pores and fissures of rocks and may form underground rivers, wells, or springs.

Springs.

Springs are of three kinds:—Dip, Fissure, and Junction.

(1) *Dip Springs* are those formed by water flowing underground along the dip of the strata until it reaches an outlet.

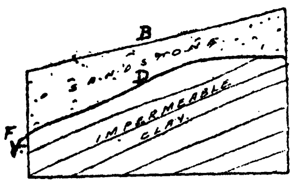


Fig. 90.
Dip Spring.

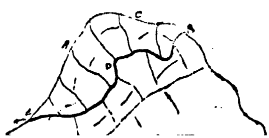


Fig. 91.
Fissure Spring.

If rain should fall on B, it might percolate through the porous sandstone deposit BD, and then flow along the dipping strata

DF. On reaching F, where the strata end, it would issue as a Dip Spring.

(2) *Fissure Springs* are plentiful in irregularly jointed strata, where the water flows along the fissures until it is forced outwards by superincumbent pressure.

Some of the water falling on ACB enters the fissure CD, to emerge at E, as a Fissure Spring.

(3) *Junction Springs* are produced by underground water meeting a geological formation of a less permeable character. This forces the water to the surface.

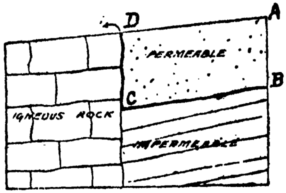


FIG. 92.
JUNCTION SPRING.

Water percolating through AB flows along BC, and meeting the impermeable rock CD, is forced upwards to the surface at D where it forms a Junction Spring.

Artesian Wells.—Advantage is often taken of the stores of underground water for irrigation purposes or for supplementing the water supply of towns. A plentiful supply of water can often be obtained by making a boring to a considerable depth, dependent upon the rainfall and the geological formation of the district. This is especially manifest where the formation

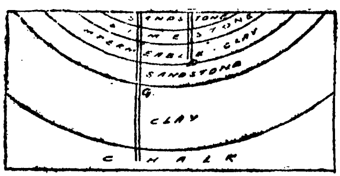


FIG. 93.
ARTESIANS WELLS.

is of such a character as that shown in the sketch. Rain falling on ABC percolates through the sandstone and limestone, and collects in the hollow at D. If a boring BD is made, the water, relieved of superincumbent pressure, flows upwards to the surface at B. Should this water be exhausted, the boring may be continued to a greater depth, or a second boring, such as FG, might be made which would tap the water that has fallen at H and I. The temperature of the water which rises upwards is dependent upon the character of the rocks below. It is usually very cold.

Geysers.—In some parts of the world, however, the water is *hot*, and is ejected in fountains of varying height. This action is due to the condensation of the steam in the upper part of the geyser, which diminishes the pressure on the heated water below. The water below, thus relieved of pressure, is at once converted into steam, and it is the violent explosion of this steam that is often sufficient to shoot the water out of the pipe as an eruptive fountain.

Mineral Springs.—Underground water acts chemically upon the rocks through which it flows, and frequently contains mineral matter such as *salt*, *sulphur*, *iron*, and *calcium carbonate* in solution. Springs containing these minerals often have a medicinal or an economic value.

Stalactites and Stalagmites are found on the roofs and floors of caves respectively, and are caused by the deposition of calcareous matter, when the water containing it is evaporated.

Epigene Agents.

We may now summarise the chief superficial or epigene agents affecting the earth's crust.

(1) *Aeolian Agents* or *Winds*, which produce storms at sea and on land, and help to disintegrate rock surfaces. On some coasts they form hills of sand called *dunes*.

(2) *Ice*, such as frost, snow, and glaciers, which break down and erode rock surfaces, and transport much material, especially in cold climates.

(3) *Rivers*, which erode, dissolve, transport, and deposit material. The deposition is generally in layers and is called *alluvium*.

(4) *Lakes*, which are hollows for the collection of transported material, and also for the remains of fresh water organisms.

(5) *The Sea*, which is the great depository for inorganic terriginous material, and also for marine organic remains. It has generally a destructive action upon the shores, although in some parts the sea is *adding* material to the land.

(6) *Plants* and *Animals*, which have a *destructive* action upon rocks, *e.g.*, the breaking up of rocks by the growing roots of plants; or a *reproductive* action as shown in the formation of peat, coral, and limestone.

The materials transported by means of water and deposited in layers or strata, are called sedimentary rocks.

Sedimentary Rocks.

Clay, *Sand*, and *Limestone* are three of the principal sedimentary rocks.

Clay is often formed by the decomposition of granite and other igneous rocks. Granite consists of quartz, felspar, and mica. *Quartz* or silica is a hard substance, usually white in colour, and is not readily dissolved. *Mica* consists of shining flakes that can be easily scratched with a knife. *Felspar* is a silicate of alumina with a certain amount of lime, soda, or potash, and it is from felspar that clay is chiefly derived. Some of the constituents of the felspar are dissolved by water and are carried away in solution, leaving the clay (hydrous silicate of alumina) behind.

Clay is soft, sectile, and may be readily moulded into various shapes. There are many kinds of clay, differing in colour and composition, of which the following are the best known.

(1) *Kaolin* or *China Clay*, a decomposition product of felspar, used for making porcelain or china.

(2) *Pipe-Clay*, a fine white plastic clay, contains more silica than (1), used for making pipes.

(3) *Potter's Clay* contains more impurities than (1) or (2).

(4) *Boulder Clay*, an unstratified clay with boulders, the result of ice action.

(5) *Brick Clay*, a mixture of fine clay and sand, contains more iron than (1), (2) or (3).

(6) *Shale*, a finely laminated clay.

(7) *Fire Clay*, a non-alkaline clay, withstands heat.

A clay formation is comparatively impermeable and forms a suitable soil for the growth of wheat.

Sandstone is composed of round or angular grains of sand cemented or pressed together. It has usually been formed in shallow water. Siliceous, calcareous, ferruginous, and dolomitic sandstones have their grains cemented with silica, calcium carbonate, iron, and dolomite respectively. Sandstones vary in colour and composition. They generally contain one or more of the following substances, in varying proportions:—quartz, felspar, mica, clay. Brown stains of iron oxide often appear in sandstones that are exposed to the air.

Varieties of Sandstones.	Characteristics.
Freestone	Homogeneous in composition, ana forms a building stone, easily worked.
Flagstone	Occurs in thin layers that are easily separated, contains clay, used for paving purposes.
Grit	A coarse sandstone, cemented with quartz.
Greensand..	Contains glauconite (a green material).
Carbonaceous Sandstone ..	Contains carbonaceous material.
Micaceous Sandstone	Contains mica, and is very soft.

Limestone varies considerably in colour, composition, and method of formation. It has usually been formed in comparatively deep water, and consists of carbonate of lime with an admixture of clay, sand, and other impurities. Limestones are often named after the fossils they contain, *e.g.*, Nummulitic Limestone.

Varieties of Limestone.	Characteristics.
Chalk	White, soft, fine-grained, contains minute shells of foraminifers, etc.
Oolite	Contains minute, rounded grains (*oon*=an egg).
Dolomite or Magnesium Limestone	Contains Magnesia and Lime.
Lacustrine Limestone	Formed in lakes in thin layers, fine-grained, soft, grey in colour.
Carboniferous Limestone ..	Compact, contains remains of crinoids, corals, etc.

Argillaceous, siliceous, ferruginous, and carbonaceous limestones contain a large proportion of clay, silica, iron, and carbon respectively.

Flints, the siliceous remains of sponges, etc., are often found in chalk. *Marl* is a mixture of limestone and clay, and forms a good soil for market gardening.

Soil

Formation.—Soil is formed by the distintegrating action of epigene agents upon rock surfaces. Water, for example, enters the interstices of rocks, freezes, expands, and thus breaks the rock mass into fragments in the course of time. The chief agents in soil formation are the following:—

(1) Rain and running water tend to separate and wash away the particles from a higher to a lower level.

(2) Frost disintegrates rocks as described above.

(3) Wind removes the smaller particles. The *loëss* of Russia and China are wind-blown deposits.

(4) Changes of temperature cause rocks to expand or contract, and this frequently leads to their disintegration.

(5) Animals separate the particles, *e.g.*, ploughing by man, burrowing by rabbits.

(6) Roots of plants force the particles of soil asunder.

Plant Food in Soils.—The clay in soil provides the plant with iron, calcium, magnesium, potash, and sodium, while decomposing vegetable and animal matter furnish phosphorus, nitrogen, and sulphur. The soil should be properly drained to enable the roots of plants to obtain the requisite quantity of air and water. Lime is often added to aid in nitrification and to facilitate the work of bacteria.

Classification of Soils.—Soils may be divided into two kinds—sedentary and drift—according to their geological formation.

Sedentary soil is that which has been weathered from hard rocks *in situ*. If we examine a district of limestone formation, we usually find the upper layers of the limestone have been more or less weathered by epigene agents into soil containing a great amount of vegetable matter. Below this upper soil is a *subsoil* containing large stones and a smaller proportion of vegetable matter. The soil and subsoil have been formed from the hard rocks below, and they are consequently sedentary in character.

Drift soil has drifted or been carried from its original position. In many parts of the London district, for example, the upper rocks consist of a foot of soil, and a subsoil of three feet of brick-earth resting upon thirty feet of Valley Gravel, all of which have been brought from a considerable distance and have been deposited in their present position by running water.

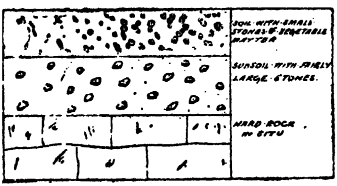


FIG. 94.
SEDENTARY SOIL.

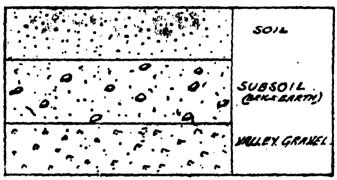


FIG. 95.
DRIFT SOIL.

Soils are also classified according to their composition.

Classes of Soil.	Usual Conditions of Formation.
Calcareous or chalky	Originally deposited in deep seas.
Clay	(*a*) Fairly deep sea, *e.g.*, London Clay, (*b*) from the weathering of granite.
Marl (Chalk and Clay)	Alternating conditions of sea and land.
Sandy	River, estuary, and tide.
Loamy	Alternating conditions of (*a*) shallow water (sand), (*b*) deep water or land (clay).

Soil Temperature.—The temperature of the surface soil is usually different from the underground temperature, and it is interesting to compare the readings of the thermometer placed six inches below the surface, with one at a depth of six feet. If a graph be drawn, it will be observed that the latter does not register such great extremes as the former, and that the graph is more uniform. At a great depth a thermometer would not be appreciably affected by the temperature of the atmosphere.

Hypogene or Subterranean Agents.

Volcanoes.—A typical volcano consists of a throat, pipe, or fissure communicating with the interior of the earth out of which gases, steam, lava, and rock fragments are, or have been, ejected. There are three kinds of volcanoes.

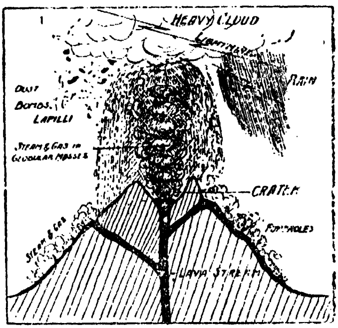


Fig. 96.
Diagrammatic Section of Volcano.

(1) Permanently active, *e.g.*, Stromboli in the Mediterranean. Such volcanoes being constantly in eruption are not very destructive.

(2) Intermittent, *e.g.*, Vesuvius in Italy. Eruptions from intermittent volcanoes are often of a violent character, especially if the period of rest has been a lengthy one.

(3) Extinct, *e.g.*, Arthur's Seat in Edinburgh. Such volcanoes have not been in eruption within historic times.

The chief volcanic materials ejected during an eruption are the following:—

(1) *Lava* is a molten rock which flows at a rate dependent

partly on its viscosity and partly on the slope of the country over which it is poured. Lavas often form *dykes* across a country, and their structure is of a crystalline character, the size of the crystals being *large* if the rate of cooling is *slow*. The hexagonal columns of the Giant's Causeway and Fingal's Cave are ancient basaltic lava flows.

(2) *Dust* is formed from exploded fragments. The finer dust may remain in the atmosphere for an indefinite period.

(3) *Lapilli*, *Cinders*, and *Pumice* are stones of varying sizes, and frequently contain small openings, out of which gases have escaped.

(4) *Bombs* are molten lava of an approximately oval form, which have been exploded from the volcano.

(5) *Tuff* is fine volcanic mud.

(6) *Gases*, chiefly steam, carbon dioxide, chlorine, fluorine, and sulphur dioxide, escape from the volcano in great quantities, and for a lengthy period. The "burning" appearance associated with volcanic activity is the reflection of the molten lava in the throat of the volcano upon the clouds of steam which collect above the crater. From these clouds heavy showers of rain descend.

Distribution of Volcanoes.—Most volcanoes are found on the borders of the continents and oceans, and frequently are near great mountain chains. This proximity of volcanoes to mountain chains points to the connection between volcanic activity and the movement which elevated those mountains. The Pacific Ocean is girdled by a line of volcanoes, and the student should trace this line from Cape Horn, along the Andes, Central America, Mexico, North-West America, the Aleutian Islands, the Kurile Islands, Japan, Formosa, the Philippines, the Moluccas, New Guinea, and New Hebrides to New Zealand. A branch line extends through Java and Sumatra. Other volcanoes are situated on islands, *e.g.*, Etna and Hecla.

Earthquakes.—These are disturbances of the Earth's crust by some internal force. They are of daily occurrence, and are registered at various seismological stations. It is found that earthquakes occur most frequently in the neighbourhood of volcanoes, and it is most likely that they are due to a weakness in the Earth's crust. The earthquake shock proceeds from its centre in concentric waves, which affect not only the land, but also the ocean, the *great sea wave* often being very destructive.

Elevation and Depression.—The Earth's crust is subject to vertical movements, that is, some parts are being vertically elevated, while others are being vertically depressed. An evidence of elevation is seen in the raised beaches which are found in many parts of the world. In Scotland, for example, they occur at various heights, sometimes being one hundred feet above their original position. On the other hand, the discovery of submerged forests, of the glaciated fiords of Norway, and of numerous fossil plants and animals, is a proof that certain parts of the earth are sinking.

MINERALS.

With the exception of coal, salt, and a few other minerals, no satisfactory explanation has yet been given to account for the presence of many of our most valuable and useful minerals in the rocks of certain districts.

Coal.—This mineral, however, is known to be of vegetable origin, and has been formed for the most part of forests which flourished in the Carboniferous Age, when there must have been a very hot and moist climate, with a plentiful supply of carbon dioxide. Coal, therefore, contains plant constituents, *e.g.*, carbon, hydrogen, oxygen, and nitrogen, and it is interesting to compare the constituents of the different kinds of coal with the constituents of peat.

VARIETIES.	CARBON.	GAS (H.O.N.).
Anthracite	92%	8%
Coal	82%	18%
Lignite	66%	34%
Peat	60%	40%

Graphite is probably an altered anthracite, and consists almost entirely of carbon.

Iron is frequently found in layers or in veins. Its chief varieties may be distinguished by their colour of streak, *limonite* being yellow, *haematite* red, *magnetite* black, and *Spathic iron ore* grey.

THE WORLD'S MINERALS.

The following are the principal minerals found near the earth's surface. The countries mentioned are those in which the minerals are obtained in the greatest abundance. Countries such as China, which contain *undeveloped* mineral wealth, have been omitted. On the accompanying map the name of the mineral has been printed upon the country which produces it in the greatest quantity.

Diamonds.—The diamond is a pure form of carbon. The mines of Kimberley, in Cape Colony, now produce 98% of the diamonds of the World. Brazil still exports *black* diamonds.

Gold.—Gold is obtained from quartz by crushing and smelting and from gravels by washing. It is chiefly used for the making of coins and jewellery. The chief gold producing countries are the Transvaal (Rand); United States (Colorado, California, South Dakota, Montana, Nevada, Alaska); Australasia (West Australia, Victoria, Queensland, New Zealand); Canada (Yukon, British Columbia); Mexico; India; Venezuela (El Callao); and British Guiana.

Silver.—Silver is used in the arts and also for the making of coins. The chief countries are United States (Colorado, Montana, Utah, Idaho, Arizona), Mexico, Australasia, Germany, Bolivia, Spain, and Peru.

Copper.—Copper is used for the making of coins, brass (alloyed with zinc), bronze (alloyed with tin), and electrical apparatus. Countries are United States (Keweenaw Peninsula, Montana, Arizona), Spain and Portugal, Chili, Japan, Germany, Australasia, Mexico, Canada, and Russia.

Coal.—Coal is used for smelting iron-ore, generating steam, heating, and also for the making of coal-gas and coke. United States, England, South Wales, South Scotland, Germany, France, Austria, Hungary, Belgium, Russia, Japan, Canada, New South Wales, Spain, Brazil, and New Zealand.

Iron.—Iron is the most useful of all metals. It is necessary for the making of steel, and those countries which produce the greatest amount of iron-ore have developed valuable steel industries. United States (near Lake Superior), Great Britain, Germany, Luxemburg, France, Belgium, Austria, Hungary, and Russia.

Lead.—Lead is chiefly used for the making of lead-piping. United States, Spain, Germany, United Kingdom, and Mexico.

Zinc.—Zinc is alloyed with copper to make *brass*, and is used for the coating of iron to make *galvanised iron*. Germany, Belgium, United States (Kansas and Missouri), France, and the British Isles.

Tin.—Tin is alloyed with copper to make *bronze*, and is used for coating iron and steel for the making of *tin-plate.* Straits Settlements, Banka and Billiton, England (Cornwall and Devon), Bolivia, and Tasmania.

Petroleum.—Petroleum is a natural oil obtained from the rocks, and is used for lighting and heating purposes. United States, Russia (Caucasia), Austria-Hungary, Burma, Canada, and Sumatra.

Sulphur.—Sulphur is found most abundantly in volcanic districts. Italy, Japan, Spain, and the United States (Utah).

Mercury.—Mercury or Quick-silver is used for the making of mirrors, and for the extraction of gold. Spain, United States, Austria, Mexico, and Russia.

Salt.—Salt is obtained in the United States, England, Russia, Austria, Spain, India, Germany, and France.

Graphite.—Graphite, Black-lead, or Plumbago is used for the making of lead pencils. Ceylon produces the largest quantity.

Nickel.—Nickel is used for the making of small coins and for the coating of iron and steel. It is found in Canada and New Caledonia.

Platinum.—Platinum is not affected by acids, and is therefore of great value in chemical laboratories. It is obtained in the Ural Mountains.

Aluminium.—Aluminium is a constituent of clay. The United States produces the greatest quantity.

Cobalt.—Cobalt is chiefly used for the making of blue paint. New Caledonia, Australia, and Germany furnish the largest supplies.

Nitrate of Soda is used as a fertilizer, and is found in Chili.

Phosphates are found in the United States (Florida, South Carolina, and Tennessee), and are also used as fertilizers.

PLANTS AND ANIMALS.

FOREST LANDS.—Forests are dependent upon a suitable soil, temperature, and rainfall. The most luxuriant forests are found in those parts of the tropics where there is great heat, excessive evaporation, and an abundant rainfall.

TROPICAL FORESTS.

TROPICAL FORESTS are found at or near the sea-level in the basin of the Amazon, the *tierra caliente* of Mexico and Central America, the basins of the Congo and Niger, the West African coast-land, South-Eastern Asia, the East Indies, and North Australia.

1. **American Tropical Forests.**—The most valuable forest trees of the Selvas are *mahogany*, *rubber*, *logwood*, *Brazil-wood*, *cinchona*, and *rosewood*. Other characteristic trees are *palms*, *mimosas*, *bamboos*, and an endless variety of *lianas* or climbing plants. The cultivated tropical shrubs and plants are *maté*, *sugar-cane*, *coffee*, *cotton*, *tobacco*, *maize*, *manioc*, *cassava*, *rice*, and *arrowroot*. American forests are remarkable for their wonderful *insect* life. *Reptiles*, *birds*, and *monkeys* also abound, but there is an absence of large wild animals, the *puma*, *jaguar*, *tapir*, *llama*, and *sloth* being much inferior to the lion, tiger, elephant, camel, and other large animals of the Old World.

(2) **African Tropical Forests** are commercially important for their *timber*, *gums*, *rubber*, *indigo*, and *palm-oil*. The agricultural products of this region are *bananas*, *cocoa-nuts*, *coffee*, *millet*, *kola-nuts*, *ground-nuts*, and *cotton*. The three last-mentioned products are found chiefly in the west. The *baobab tree* and *palms* of various kinds grow practically everywhere.

These almost impenetrable forests are the home of the *gorilla*, *chimpanzee*, *hippopotamus*, *rhinoceros*, and *crocodile*, but "big game," such as the *lion*, *leopard*, *giraffe*, *antelope*, and *zebra*, prefer the savannas or park-lands of the more elevated country to the east and south.

(3) **Asiatic Tropical Forests.**—The forests of south-eastern Asia and the East Indies produce ornamental woods, such as *teak* and *ebony*, together with *palms* and *bamboos* of various kinds.

The agricultural products include *rice*, *indigo*, *tea*, *sugar*, *rubber*, *cocoa*, and *spices*. There is a great variety of *birds* and *reptiles*.

(4) **Australian Tropical Forests.**—The indigenous trees of Australia are very different from those of the rest of the world, and seem to indicate that there has been little migration between this and the other continents for long geological periods. The principal trees comprise many varieties of *eucalyptus*, which furnish valuable timber, *acacias* (wattles), which sometimes yield *gum*, *tree-ferns*, and *climbing plants*. The native animals are also peculiar, including a variety of *marsupials* (the *kangaroo*, *wombat*, and *opossum*), together with the *dingo*, *duck-bill*, and *emu*. The birds are remarkable for their brilliant plumage, *e.g.*,

the *parrot*, *cockatoo*, and *lyre-bird*. The reptiles include *snakes* and *lizards*. *Alligators* are plentiful. *Bananas*, *oranges*, *sugar*, and *cotton* are now being cultivated in tropical Australia.

The chief domestic animals of the Tropics are the *horse* (absent from Central Africa and the Amazon Valley), *sheep*, *cattle*, *dromedary* (one hump), and *elephant* (S.E. Asia).

Temperate Forests.

TEMPERATE FORESTS.—The temperate forests are found immediately to the north and south of the Tropics, namely, in the Temperate Zones, except where the land is *elevated*. The Temperate Forests vary considerably in character, according to their situation, those in the south being mostly *evergreen*, while those in the centre and north are *deciduous* and *coniferous* respectively. The evergreen, deciduous, and coniferous regions do not extend in zonal belts, their extension being greatly affected by the height of land, the climate, and the soil.

(1) **The Evergreen Temperate Forests** are best represented in the countries bordering the Mediterranean. Characteristic trees are the *cypress*, *olive*, *evergreen oak*, *laurel*, *privet*, *holly*, *cedar*, *yew*, *myrtle*, *orange*, and *lemon*. Though the prevailing tone of the vegetation is evergreen, many deciduous trees are also present, such as the *sweet-chestnut*, *mulberry*, and *hazel*. The chief agricultural products of this region are the *vine*, *maize*, *rice*, *raisins*, *sugar-cane*, *esparto*, *figs*, *tobacco*, and *cotton*.

The evergreen regions of the world being generally well peopled, the *wild* animals are comparatively small and unimportant. The domestic animals, however, are more numerous and more important than those in the Tropics, and include the *mule* (America and Mediterranean), *dromedary* (North Africa, Syria, and Central Australia), *Bactrian camel*, which is a two-humped camel (Central Asia and China), *donkey* (Mediterranean countries), *dog*, and *goat*; *horses*, *cattle*, *swine*, and *sheep* are generally distributed, although the two last-named animals are very seldom met with in Eastern China or Japan. Cape Colony is famous for its ostriches.

(2) **The Deciduous Temperate Forests** are those in which most of the trees shed their leaves annually. These forests are found in the New Atlantic States, around the great lakes of North America, and in Central and Western Europe (excepting the Steppes of Russia and the elevated regions). The chief trees

are the *oak*, *beech*, *ash*, *elm*, *birch*, *poplar*, *willow*, *chestnut*, *alder*, and many others. Coniferous trees are also plentiful, such as the *larch*, *spruce*, *cedar*, and *pine*.

Cereals (*wheat*, *barley*, *oats*, and *rye*), *fruits* (*apple*, *pear*, *plum*, and *cherry*), and *green crops* (*turnips*, *mangolds*, and *clover*), are often cultivated in districts where the natural forests have been cut down. The leading manufacturing nations of the world live in the deciduous forest areas, and nearly all the large wild animals have therefore been exterminated. The *fox*, *boar*, *badger*, *beaver*, *otter*, *squirrel*, *hare*, and *rabbit* are found. The domestic animals are of the greatest importance, and include the *horse*, *cattle*, and *sheep*; in the drier districts, *dog*, *pig*, and *ass*.

(3) The **Coniferous Temperate Forests** stretch across Canada, occupy the Highlands of Europe, and cover the whole of Northern Eurasia as far as the Arctic Circle, from Scandinavia to Behring Strait. Pine trees prevail also in New Zealand, Tasmania, south-east Australia, and southern Chili. These extensive pine forests have given rise to most valuable lumbering and kindred industries. The *wolf* and *bear* still linger in these forests.

TUNDRAS AND BARREN LANDS.

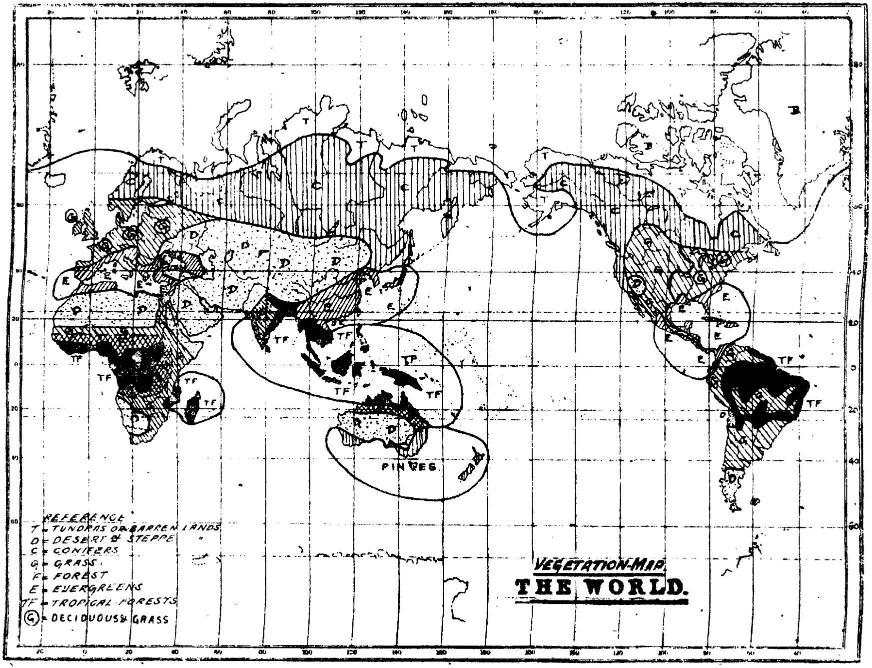
North of the conifers the vegetation becomes stunted in character, being represented by mosses and lichens, and the land is known as the *Tundras Zone*. The wild animals are hunted for their furs (*squirrel*, *sable*, *otter*, *red fox*, *marten*, *opossum*, and *sea-otter*). The *reindeer* and *Eskimo dog* are the only remaining domestic animals.

The northern islands of Franklin and most of Greenland are entirely devoid of vegetation; sea animals, such as the seal and whale, being the sole representatives of animal life.

GRASS LANDS.

Grass lands generally prevail where the rainfall is inadequate for the growth of forests. The chief grass land regions are the *Prairies* of North America; the *Llanos*, *Campos*. and *Pampas* of South America; the *Savannas* of Sudan and Rhodesia; the *Veldts* of South Africa; the *Steppes* of Central Eurasia; and the *Downs* of Australia and New Zealand.

The Prairies stretch from Canada to Mexico across the central and western portion of the United States, where the


VEGETATION-MAP
THE WORLD.
REFERENCE
T = TUNDRAS OR BARREN LANDS
D = DESERT & STEPPE
C = CONIFERS
G = GRASS
F = FOREST
E = EVERGREENS
TF = TROPICAL FORESTS
(G) = DECIDUOUS & GRASS
PINES

[To face p. 118.

rainfall is scanty. On these prairies are the great ranching stations, *cattle* and *sheep* being reared in countless numbers.

The Llanos of the Orinoco are rich grassy plains in the basin of that river, and provide pasturage for large numbers of *horses* and *cattle*. They often become parched during the dry season.

The *Campos*, *Cataangas*, or Tablelands of Brazil are chiefly devoted to the rearing of *cattle*.

The *Pampas* of South America extend from the forests of Gran Chaco in the north, to the plains of Patagonia. They cover the greater portion of Argentina and support great numbers of *sheep* and *cattle*.

The *African Savannas* are the grass lands of tropical Africa, and are suitable for *cattle*-rearing. In Rhodesia the tse-tse fly is a source of great trouble. The Savannas of British East Africa provide the best hunting-ground for big game. The baobab and other trees which afford cover for this game, impart to the Savannas a park-like appearance.

The *Veldts* of British South Africa are suitable, for the most part, for the rearing of *cattle*, *sheep*, and *goats*. In many parts the rainfall is totally inadequate for agricultural operations.

The *Steppes of Eurasia*, especially near the Caspian and Aral Seas, afford scanty pasturage for *horses*, *sheep*, *goats*, and *cattle*. The tribes are compelled to live a nomadic life.

The *Downs of Australia* and *New Zealand* are the chief *sheep*-rearing districts in the world, and contribute largely to the wealth of Australasia.

Deserts.—The grass lands of scanty rainfall pass insensibly into the desert regions. The hot deserts of the world are found either near the Tropics of Cancer and Capricorn, or on the great tablelands in the interior of the continents.

Vegetable Productions in Different Countries.

The following are the chief vegetable productions of the world, and the countries in which they are most extensively grown:—

Wheat ..	United States, Russia, France, India, Austria, Italy, Germany.
Maize ..	United States, Austria, Italy, Roumania.
Oats ..	United States, Russia, Germany, the British Isles, France, Austria.
Rye ..	Russia, Germany, Austria, France, British Isles.
Barley ..	Russia, Austria, Germany, British Isles, France.
Beet Sugar.	Germany, Austria, France, Russia, Belgium, Holland.
Sugar Cane	Java, Cuba, Hawaiian Islands, Brazil, Mauritius, Queensland.
Cotton ..	United States, India, Central and East Asia, Egypt, Mexico.

Tea ..	China, Assam, Ceylon, Japan, Java, Sumatra, Natal.
Rice ..	Burmah, India, French Indo-China, Siam, China, Japan, United States.
Coffee ..	Brazil, Java, West Indies, Central America, Arabia, India.
Cocoa ..	Ecuador, Trinidad, Venezuela, Brazil, Ceylon, West Indies.
Jute ..	Bengal.
Hemp ..	The Philippines, Yucatan, Italy, Russia.
Tobacco ..	United States, Cuba, Mexico, the Philippines, East Indies.
Opium ..	India, Persia, Asia Minor, China.
Vines ..	France, Italy, Spain, Austria, California, Victoria, Portugal.
Olives ..	Italy, France, Algeria, Spain, Turkey, Syria.
Flax ..	Russia, Belgium, United States, Ireland, India.
Oranges ..	Spain, Portugal, Italy, Madeiras, Florida, California.
Dates ..	Algeria, Africa, Arabia, Turkey, Egypt, Persia.
Bananas ..	West Indies, Canaries, Costa Rica, Fiji, Queensland.
Sago ..	East Indies.
Tapioca ..	Tropical America, Africa.
Arrowroot	West Indies.
Rubber ..	Brazil, Tropical Africa, Central America, Guiana.
Potatoes ..	Germany, Ireland, Algeria, Bermudas.
Apples ..	Canada, United States, Tasmania, British Isles.
Timber ..	Canada, United States, Scandinavia, New Zealand, Central America, Russia.
Currants ..	Greece, Turkey,
Figs ..	Italy, Asia Minor, Greece.
Prunes ..	France, Bosnia, Servia.
Cocoanuts..	The Ocean Islands and near the coasts of tropical countries.
Spices ..	East Indies, Chili, Cayenne, Jamaica.

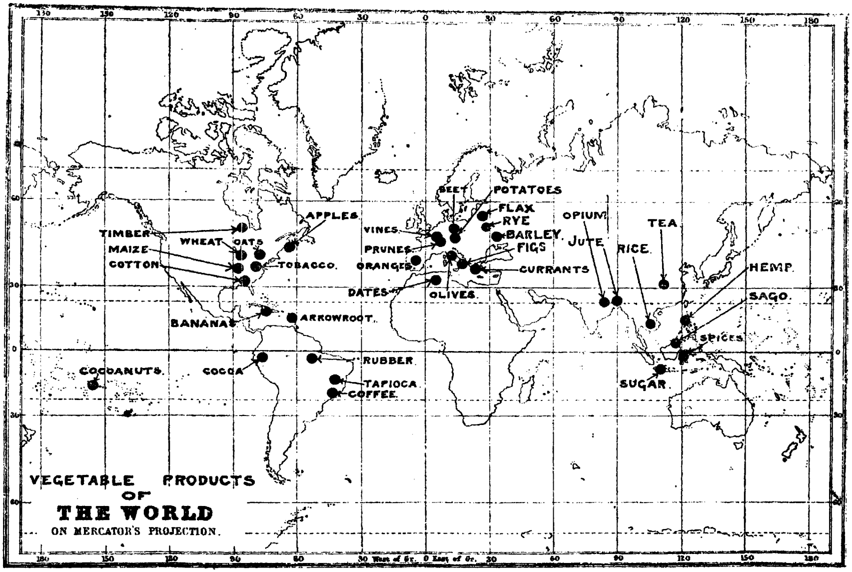
ANIMALS.

Animals.—The most useful animals are *cattle*, *horses* (not used much in tropical countries), *sheep*, *reindeer* (in Arctic regions), *pigs*, *mules* (especially employed in America and the Mediterranean countries), *camels* (used in the deserts of Asia, Africa, and Australia), *llamas*, *donkeys*, *alpacas* (Andes), *elephants*, *yaks* (employed in Tibet), and *dogs*.

Sea Animals and Fishing Grounds.—The great fishing grounds are in the North Temperate Seas.

(1) The *North Sea*, especially near the Dogger Bank, off the Lofoten Isles, near the coast of Yarmouth, off the Cornish coast, and near the Isle of Man. Trawling is employed for the capture of *haddock*, *plaice*, *turbot*, *soles*, and other fish that swim to a great depth. Drift-net fishing is employed for such fish as swim near the surface, and which are found in shoals, such as the *herring*, *mackerel*, and *pilchard* that appear at different parts of the coast according to the season of the year.

(2) The *Mediterranean Sea* is famous for its *tunny* and *sardine* fisheries.


VEGETABLE PRODUCTS OF THE WORLD
ON MERCATOR'S PROJECTION.
TIMBER
MAIZE
COTTON
WHEAT
OATS
TOBACCO.
APPLES.
BANANAS
ARROWROOT.
COCOANUTS.
COCOA
RUBBER.
TAPIOCA.
COFFEE.
VINES.
PRUNES.
ORANGES.
DATES.
OLIVES.
BEET
POTATOES
FLAX
RYE
BARLEY.
FIGS
CURRANTS
OPIUM
JUTE
RICE.
TEA.
HEMP.
SAGO.
SPICES.
SUGAR.
30 West of Gr. 0 East of Gr. 30

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(3) The *Banks of Newfoundland* are excellent fishing grounds for *cod, herring*, and *lobsters.*

(4) *Off British Columbia.*

(5) *Off Nova Scotia and the New Atlantic States.*

(6) *In certain Rivers, e.g.*, Volga for *sturgeon*, Fraser for *salmon*, Hudson for *shad*, and the Tweed for *trout.*

(7) *In certain Lakes, e.g.*, Caspian for *sturgeon*, the roe of which is sold as caviare, and The Great Lakes for *white fish.*

(8) The *Arctic Ocean*, especially near the shores of Greenland, is famous for its *whale* and *seal* fisheries.

Sponge fishing is carried on in the Mediterranean, and off the shores of Florida and the Bahamas.

Oyster beds are established along the coasts of Essex (Colchester) and Kent (Whitstable), along the Atlantic seaboard from Massachussets to Virginia, and along the French shores of the Bay of Biscay.

Pearl fishing is an important industry in the Persian Gulf, the Gulf of Manaar, and off the western and northern coasts of Australia.

Ordinary fishing near the Australian shores is greatly checked by the damage done to the nets by sharks.

Tropical seas are somewhat devoid of edible fish, although Dr. Alcock of the Indian Marine Survey reports as follows regarding the Orissa Coast of the Bay of Bengal:—

"If the regulations of the salt-excise could be modified, and if capital on a liberal scale were forthcoming, the Bay of Bengal would furnish inexhaustible supplies of dried and smoked fish, fish-oil, isinglass, and gelatine for the world in general, and of shark's fins for the China market in particular.

THE RACES OF MANKIND.

Of the world's great races, the most important are the **Caucasian** (White), the **Mongolian** (Yellow), the **Ethiopic** (Black), and the **Indian** (Red).

The **CAUCASIAN RACE** is found chiefly in Southern, Central, and Western Europe, North-East Africa, Arabia, Irania, India, South-East Asia, Polynesia, North-East Asia, America, Australia, and New Zealand. Features:—Fair complexion, long hair and ample beard, about 5ft. 9ins. in height, long head, energetic, and intelligent.

It includes—

1. The *Low Germans*, among whom are the English.

2. The *High Germans*, among whom are the Austrians.
3. The *Scandinavians*, among whom are the Icelanders.
4. The *Letto-Slavs*, among whom are the Russians.
5. The *Hamites*, among whom are the Egyptians, Berbers, and Tuaregs.
6. The *Semites*, among whom are the Arabs, Syrians, and Abyssinians.
7. The *Iranians*, among whom are the Persians, Afghans, and Kurds.
8. The *Northern Hindus*, among whom are the Hindus and Bengalis.
9. The *Southern Hindus*, among whom are the Tamils and Singhalese.
10. The *Polynesians*, among whom are the Maories and Hawaiians.
11. The *Ainus*, among whom are the people of Yezo and Sakhalin.
12. The *Caucasians* Proper, among whom are the Georgians and Circassians.
13. The *Kelto-Iberians*, among whom are the Spaniards, Welsh, and Irish.
14. The *Legurians*, among whom are the Italians.
15. The *Pelasgo-Hellenes*, among whom are the Greeks and Albanians.

The **MONGOLIAN RACE** is found chiefly in Eastern Asia, Irania, Asia Minor, Russia, the Balkan Peninsula, Hungary, Madagascar, Australia, and America. Features:—Yellow complexion, coarse hair and no beard, about 5ft. 4ins. in height, square-shaped head, prominent cheek-bones, somewhat indolent, fairly intelligent.

It includes—

1. The *Mongolo-Tartars*, among whom are the Kalmuks and Kirghiz.
2. The *Finns*.
3. The *Lapps*.
4. The *Samoyedes*.
5. The *Magyars*.
6. The *Tibeto-Chinese*, among whom are the Tibetans, Burmese, Shans, and Chinese.
7. The *Malayans*, among whom are the Formosans and Hovas.
8. The *Koreo-Japanese*, among whom are the Koreans and Japanese.

Some ethnologists consider that the *Malays* should not be classified with the Mongolians, but should be treated as a distinct race.

The **ETHIOPIC RACE** is found chiefly in Africa and America, In the latter continent they were introduced as slaves. Features:—Black complexion, short woolly hair and scanty beard, long skull, about 5ft. 8ins. in height, thick lips, indolent, unintellectual.

It includes—

1. The *Mandigoes* and *Songhays* of West Sudan.
2. The *Ewes* and *Yorubas* of Guinea.
3. The *Hausas* and *Bornus* of Central Sudan.
4. The *Bantus*, among whom are the Zulus, Kaffirs, and Hereros.
5. The *Fulas* of Sudan, the *Negritoes* of the Congo, the *Bushmen* of the Kalahari desert, and the *Hottentots* of the Zambesi.
6. The *Papuans*, who live in New Guinea.
7. The *Melanesians*.
8. The *Australian* "*blacks*," who are now dying out.

The **INDIAN RACE** is found chiefly in America. Features:—Copper-coloured complexion, long hair and scanty beard, aquiline nose, tall, massive jaws, impassive and fairly intelligent.

It includes—

1. The *Eskimos* of the Arctic shores.
2. The *Athapascans* of North Canada, among whom are the Apaches.
3. The *Snakes* of the Western States.
4. The *Siouans* in Central North America, including the Crows.
5. The *Creeks* in the United States, including the Choctaws.
6. The *Algonquins* in North America, including the Ojibwas.
7. The *Iroquoians* in the Eastern States, including the Mohawks.
8. The *Aztecs* of Mexico, the *Caribs* of the West Indies, the *Peruvians*, and the *Guaranians* of Brazil.

Of the four great races, the Caucasian is the largest and most important. England has a population of 31 millions, and if we compare the races of the world with the population of England, we get the following table.

The *Caucasian* Race	25 times that of England.
The *Mongolian* Race	17 times that of England.
The *Ethiopian* Race	6 times that of England.
The *Indian* Race	$\frac{2}{3}$ times that of England.

Taking England, with its area of 50,000 square miles, and its average population of 600 persons to a square mile, as our standard of reference, we may compare the six great continents into which the land surface of the world is divided, as follows:—

Australia	60 times England	1 person to the square mile.
Europe	74 ,, ,,	100 persons ,, ,,
North America	172 ,, ,,	10 ,, ,, ,,
South America	140 ,, ,,	5 ,, ,, ,,
Africa	230 ,, ,,	20 ,, ,, ,,
Asia	346 ,, ,,	50 ,, ,, ,,

The undetermined continent of Antarctica is not included in the above table.

RELIGIONS OF THE WORLD.

The following table gives a comparison between the principal religions of the world, in terms of the population of England:—

Christians	15 times the population of England.
Buddhists	15
Brahmins	7
Mohammedans ..	5
Jews	$\frac{1}{3}$
Heathens	5

Of the *Christians* about half are *Roman Catholics*, the remainder being chiefly *Protestants* or belonging to the *Greek Church*.

DENSELY PEOPLED REGIONS.

The chief regions of dense population in the world are the following:—

(1) *London* and the *industrial parts of Great Britain*, the latter largely due to the abundance of coal and iron, and an easily accessible sea-coast.

(2) *Belgium*, especially Antwerp, on account of the iron and coal, good soil, excellent means of communication, proximity to the ocean, and the surrounding European markets.

(3) *Holland*, owing to its situation at the mouth of the Rhine and its good soil.

(4) *Germany*, especially the Rhine Valley, Silesia, and Saxony, due to the minerals, and also to the easy means of distribution of goods by land and sea.

(4) *Lombardy*, especially the neighbourhood of Milan and Venice, owing to the textile industry and the waterways.

(6) The *Nile Valley*, due to the good soil, accessibility to the Mediterranean which is one of the great trade routes of the world.

(7) The *Lower Ganges and Indus Valleys*, on account of the rich soil, river communication, and sea-coast.

(8) *China Proper*, due to a rich agricultural region and its navigable rivers.

(9) *Hondo*, due to the important agricultural and manufacturing industries of Japan, and its excellent sea-coast.

(10) The *Atlantic States of America*, on account of the minerals, manufactures, and means of distribution.

Thus the chief regions of dense population are found in the river valleys, the areas that are rich in coal and iron, the manufacturing districts, and the districts that are near good harbours and the great commercial routes of the world.

THINLY PEOPLED REGIONS.

The thinly peopled regions of the world are the cold deserts (Tundras and Patagonia), the hot tablelands of Utah, Atacama, and Brazil; the deserts of Sahara, Kalahari, Arabia, Irania, Gobi, and Central Australia; Tibet; mountainous country such as the Rockies, Andes, Alps, Pyrenees, and Himalayas; and the regions of dense tropical vegetation, such as the Selvas and the forests of the Congo.

THE LARGEST CITIES OF THE WORLD.

There are thirteen cities in the world that have a population of upwards of one million of inhabitants, namely:—London (4·5 millions), New York (3·4 millions), Paris (2·7 millions), Berlin (1·9 millions), Chicago (1·7 millions), Vienna (1·7 millions), Pekin (1·5 millions), Tokio (1·4 millions), Petrograd (1·4 millions), Philadelphia (1·3 millions), Calcutta (1·3 millions), Constantinople (1·1 millions), and Moscow (1 million).

All the above mentioned cities, with the exception of Calcutta, are situated in North Temperate Regions.

(1) **London.**—*Advantages.*—Capital of the British Empire, excellent harbourage, largest ships can reach the city, faces Europe, roads and railways converge to it, canal communication, scarp-lands some distance removed, double tide, dry and healthy climate, financial centre, old established city, centre of the land hemisphere, many manufactures, suburbs of market gardens, brick-clay deposits near, room for expansion, great historical interest.

Disadvantages.—Mineral areas distant, sandbanks in estuary, congested and badly-planned East End, large manufacturing areas distant.

(2) **New York.**—*Advantages.*—Good harbour with extensive frontage, faces Europe, important towns near, coal and iron plentiful, easy access to interior, especially by the Hudson and Mohawk Valley, rail and water communication with rich cotton and grain areas, not ice-bound in winter, great ocean liners, financial and manufacturing centre, regularly laid out with many open spaces, scientific administration, outlet for American produce.

(3) **Paris.**—*Advantages.*—Capital of French Empire, geographical and political centre, scarp-lands removed, railway centre, roads converge towards it, beautifully laid out, leader of "fashion," financial centre.

Disadvantages.—Large vessels cannot reach it, no minerals near.

(4) **Berlin.**—*Advantages.*—Capital of Germany, central position, financial centre, excellent railway communication, important roads (Hamburg to Breslau, Stettin to Frankfort, and Danzig to Frankfort) cross here, many manufactures, commercial centre, in level country.

Disadvantages.—Not a seaport, surrounding plain is sandy, water communication defective.

(5) **Chicago.**—*Advantages.*—Excellent position on Lake Michigan, lake-port, adapted for the largest vessels, water communication with the Atlantic and Mississippi; maize, mineral, grain, and timber country near; iron and steel industries; meat, grain, and timber trades; well-built railway centre, level country, room for expansion; developed on scientific lines; great distributing centre.

(6) **Vienna.**—*Advantages.*—Political and commercial capital of Austria, river-port, excellent strategic position which checked Mohammedan advance, commands the Adriatic to East Germany route, and also that between the Upper and Lower Danube.

(7) **Pekin.**—*Advantages.*—Political capital of China commands the roads to Mongolia, Manchuria, and the interior; railway to Hankou.

Disadvantages.—In a sandy plain, which is bleak and dreary in winter; not easily reached from the sea; non-commercial population.

(8) **Tokio.**—*Advantages.*—Capital of Japan, outlet for rice and silk districts, railway communication.

Disadvantages.—No harbour, subject to earthquakes, overcrowded.

(9) **Moscow.**—*Advantages.*—Made capital of Russia (1918). Central position, roads and railways converge towards it, centre of home trade, great distributing city, coal plentiful in the neighbourhood, forests near, many manufactures.

Disadvantages.—Lacks over-sea trade.

(10) **Philadelphia.**—*Advantages.*—On an estuary, mineral areas near (coal, iron, oil), good communication to inland districts, many manufactures.

Disadvantages.—Harbour is often frozen in winter, inland communication is not so good as that from New York into the interior.

(11) **Calcutta.**—*Advantages.*—Former capital of India, important mercantile centre, outlet for the agricultural products of the Ganges, seaport.

Disadvantages.—Hugli channel dangerous and silting up; unhealthy for Europeans in the Rainy Season, few mining or industrial districts near.

(12) **Constantinople.**—*Advantages.*—Capital of the Turkish Empire, beautiful natural harbour, important strategic position

commanding routes from Europe to Asia and from the Black Sea to the Mediterranean; of historical interest

Disadvantages.—Badly governed, overcrowded.

(13) **Petrograd.**—*Advantages.*—Former capital of the Russian Empire, river harbour, good railway and canal communication.

Disadvantages.—Often ice-bound in winter, too far from mineral and agricultural regions.

THE DISTRIBUTION AND EMPLOYMENT OF PEOPLE.

The distribution and employment of people are largely affected by superficial configuration, outline, climate, government, and inventions.

(1) **Superficial Configuration.**—(*a*) In a *hill-country* commerce is checked, communication is defective, and transport is difficult on account of the poor roads, few railways, and unnavigable rivers. The minerals usually associated with mountains and the forests of the hill slopes give employment to the people in *mining* and *lumbering*. The effect of a hill country in checking trade is illustrated by the Andean Republics. Some of the more energetic hill countries endeavour to overcome the natural difficulties by means of tunnels, etc., *e.g.*, Switzerland.

Agricultural and manufacturing occupations are usually backward in a hilly country, and towns are consequently few, *e.g.*, the Highlands of Scotland, and the Pyrenees.

(*b*) *Valley Country* is an aid to communication, transport, and commerce, *e.g.*, Valleys of the Nile, Mississippi, Ganges, and the Rhine. The river, which flows through the valley, is of great service for water-transport, and lines of telegraph, roads and railways may be easily placed near its banks.

The country through which the river flows is often well-watered, thus giving rise to agricultural operations and the establishment of towns.

(*c*) *A Plain Country*, if well-watered, is excellently adapted for communication and transport canals, roads and railways are easily made, and agricultural and pastoral occupations have room for further development, *e.g.*, Holland, Prairies, Pampas, and Central England.

(*d*) *Mouths of Rivers* usually form the natural outlet for the produce of a country, and the shipping thus provides employment for a large number of people, with the consequent building of towns, *e.g.*, London.

An estuary is more favourable for commerce than a delta. The Rhine, for example, is more suitable for commerce than the Niger.

(2) **Outline.**—If the outline or boundary of a country extends along the sea, foreign trade is facilitated, especially if the outline is irregular and anchorage is safe, *e.g.*, English harbours.

The sea serves as a defence, and the maritime interests aid in the development and enterprise of a nation. Over-sea possessions are possible, foreign markets may be established, and ports can be constructed.

On the other hand, if a country is *inland*, its communication with distant foreign countries is difficult and expensive. The boundary line may run through a region of unrest, where tariffs hinder the natural transit of goods, and few people feel sufficiently secure to settle.

(3) **Situation.**—If a country is situated near the world's great routes, trade is naturally increased. England's situation in the centre of the great commercial nations of the world is of the greatest value.

(4) **Climate.**—The climate of a country, considered especially with regard to its heat and rainfall, has an enormous influence upon the people and their occupations. In the *Tropics* the people require little food, shelter, and clothing, the sun's heat is oppressive, and the people have consequently no great necessity for exertion. Commerce is neglected, sanitation is defective, the faculties of the people are undeveloped, few large towns are constructed, and systematic or skilled labour is almost unknown.

In the *Polar* regions an abundance of food, clothing, and shelter is absolutely necessary, and the poor inhabitants expend all their energies in an endeavour to obtain a bare subsistence from their stern and barren surroundings.

The *Temperate* regions are the most favourable parts of the world for the development of the people, and there we find the largest towns, the most enterprising and intelligent people, and the most extensive commerce.

(5) **Government.**—A good government protects its people from invasion, secures the workers from interference, and ensures to them the results of their industry. Trade is encouraged by the construction of internal means of communication, the deepening of rivers, the erection of lighthouses, close supervision of the weights and measures, the possession of foreign markets, and the

publication of scientific information for the benefit of those engaged in the various industries of the country. Good governments can be relied upon to carry out their trading obligations.

(6) **Inventions.**—The chief inventions that have benefited mankind are those which have lead to increased production, or have facilitated commerce. Among the former are specially constructed machinery, the application of steam and electricity, the construction of artesian wells, and the application of chemical, botanical, medical, and other forms of scientific knowledge.

Amongst the inventions that have accelerated communication and transport, and have thereby led to increased production, are the establishment of the *telegraph* and *postal* systems, the construction of *steamships* and *ship-canals*, the increased use of *oil*, the laying down of *railways*, the boring of *tunnels*, and the use of *cycles*, *motors*, and *air-craft*.

These means of rapid transport have made it possible to exchange the manufactured goods of England for the otherwise perishable produce of far-off lands, *e.g.*, the bananas of Jamaica, and the frozen meat of Australasia.

THE WORLD'S TUNNELS.

Simplon Tunnel, between Switzerland and Italy, 12 miles long.

St. Gothard Tunnel, between Switzerland and Italy, nearly 9½ miles long.

Cenis Tunnel, between France and Italy, 7½ miles long.

Brenner Tunnel, between Switzerland and Italy, 6 miles long.

Severn Tunnel, under River Severn, G.W.Ry., 4½ miles long.

Totley Tunnel, near Sheffield, 3½ miles long.

Standegde Tunnel, near Huddersfield, L.N.W.Ry., 3 miles long.

Woodhead Tunnel, between Huddersfield and Sheffield, 3 miles long.

Chipping Sodbury Tunnel, between Sodbury and Badminton, G.W.Ry., 2 miles long.

Chinley Tunnel, on the Midland Ry., 2 miles long.

Medway Tunnel, on the S.E. & C.Ry., 2 miles long.

Bramhope Tunnel, on the N.E.Ry., 2 miles long.

Festiniog Tunnel, L.N.W.Ry., 2 miles long.

Cowburn Tunnel, Midland Ry., 2 miles long.

Morley Tunnel, near Leeds, L.N.W.Ry., nearly 2 miles long.

Box Tunnel, near Bath, G.W.Ry., 1¾ miles long.

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MATHEMATICAL, ASTRONOMICAL, AND PHYSICAL GEOGRAPHY.