R. B. Bunnett

Physical Geography in Diagrams

Praeger

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BOOKS THAT MATTER

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Preface

Physical geography is an essential prerequisite for human geography and it is, therefore, important for students to make a thorough study of the processes which operate to produce man's environment, and the physical features to which these give rise.

Throughout this book diagrams are used as the medium through which the subject is approached, because the author believes that large, well-annotated diagrams are the best way of getting most students to understand quickly geographical processes and features. The book contains over 400 line diagrams and 50 photographs, and wherever possible these are used to explain geographical principles and concepts. The text is superimposed on this foundation.

R.B.B.

Acknowledgements

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Aerofilms, at the top of pages 73 and 85; American Museum of Natural History, page 89; Ansel Adams, Magnum, page 158; H. H. Bennett, F.A.O., the top of page 162; Victor Bianchi, page 165; Camera Press, the bottom of page 166; J. Allan Cash, the bottom of page 85; H. E. Dale, United States Department of Commerce Weather Bureau, page 132; Department of Highways, South Dakota, the top of page 49; Ewing Galloway, page 59; Fairchild Aerial Surveys, the bottom of page 66; French Government Tourist Office, page 35; Geological Survey Photograph, Crown Copyright Reserved, pages 77 and 87; Hong Kong Government Information Service, page 165; Institut für Auslandsbeziehungen, top of page 66; Institut Géographique National, page 98; John Laundis, Black Star, page 60; Middle East Archives, page 42; Zambia Information Department, page 56; Paul Popper, pages 32, 72, 74, 99 and 163; Radio Times Hulton Picture Library, the top of page 38 and page 71, and the middle and bottom of page 73; Rudi Hertzog, page 68; J. K. St. Joseph, Crown Copyright Reserved, the bottom of page 96; Sky Foto, the bottom of page 38; Société Encyclopédique Universelle, the bottom of page 162; Society for Cultural Relations with the U.S.S.R., page 167; Swiss National Tourist Office, pages 50, 92, 94 and the top of page 96; United States Information Service, pages 97 and 164, and the top of page 166; Wild Heerbrugg, page 39. Those on pages 18, 26, the bottom of page 49, 76, 79 and 81 are by R. B. Bunnett.

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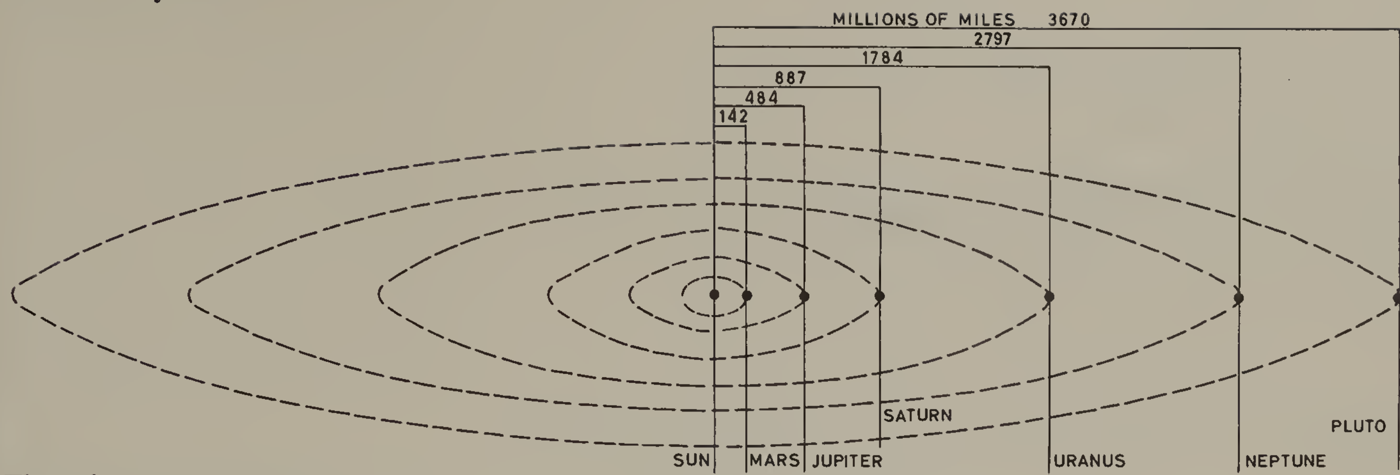
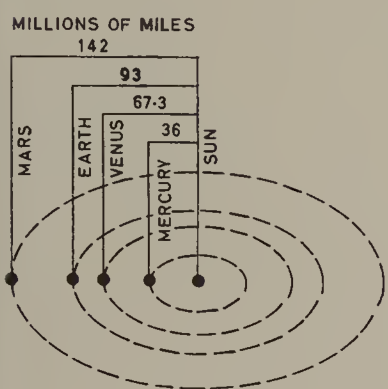
Physical Geography in Diagrams

Introduction

The Solar System

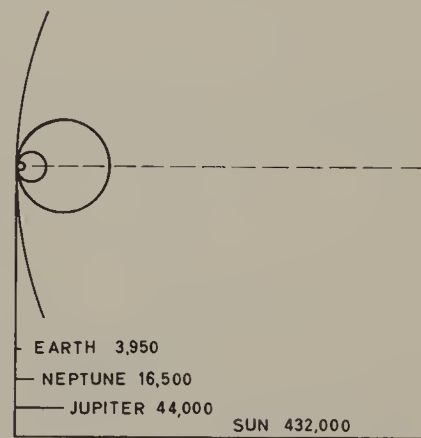


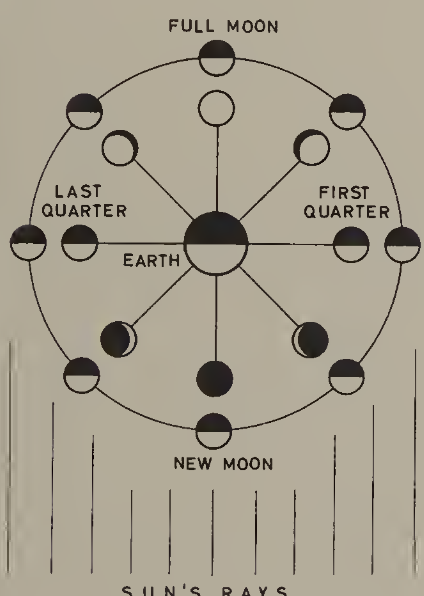
The solar system together with all the stars we can see is the GALAXY.



All the planets of the solar system revolve round the sun. The earth takes 365¼ days (called one year) to make one revolution. The moon is a satellite of the earth and it revolves round it once a month.

The sizes of some Planets (radii given in miles)





Phases of the Moon

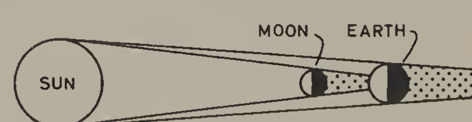
As the moon revolves around the earth the illuminated part of it varies in size. In the diagram the two circles represent moon positions. The outer circle clearly shows that exactly half the moon is illuminated all the time. The inner circle shows what the moon looks like to us on earth during its different positions. The illuminated part of the moon takes different shapes—at full moon it is a circle. Look at the moon on different nights in any one month and find out whether that part of the moon which is not illuminated can be seen.

Eclipse of the Moon

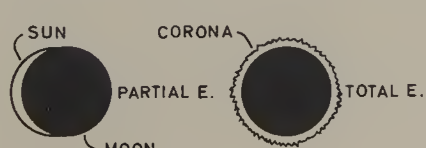
(earth comes between moon and sun)

Eclipse of the Sun

(moon comes between earth and sun)



Eclipse of the Sun as seen from the Earth



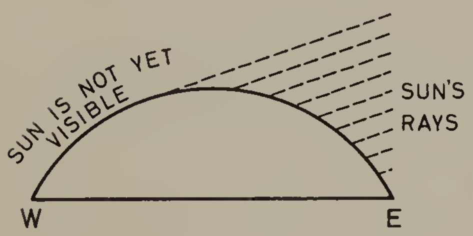
Chapter 1 The Earth

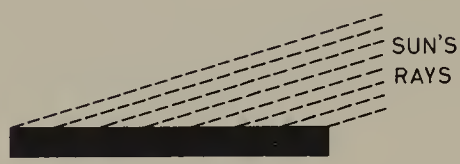
The Earth is Round

There are many simple observations we can make which tell us that the earth is round and not flat.

1 The rising sun is seen first at places in the east and later at places to the west.

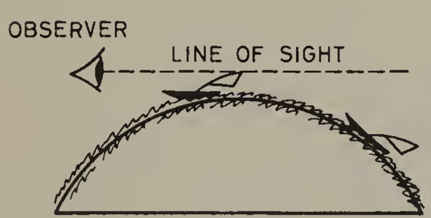
If the earth was flat the rising sun would be seen at all places at the same time.

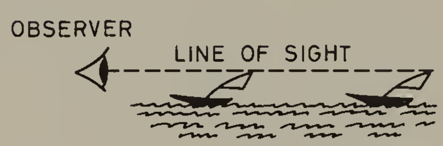




2 The observer sees only one ship. The other lies below his line of sight.

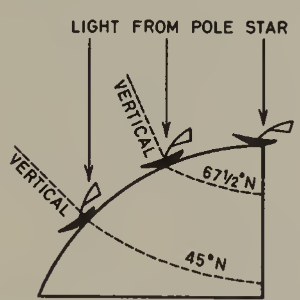
If the earth was flat the observer would see both ships.

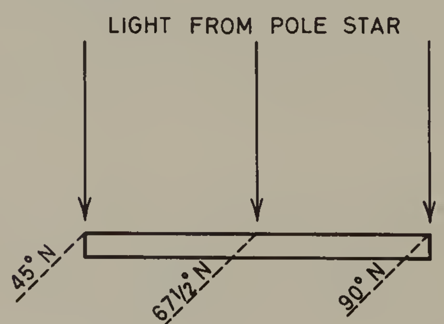




3 The height of the Pole Star in the sky varies with the latitude.

If the earth was flat the Pole Star would have the same height for all latitudes.





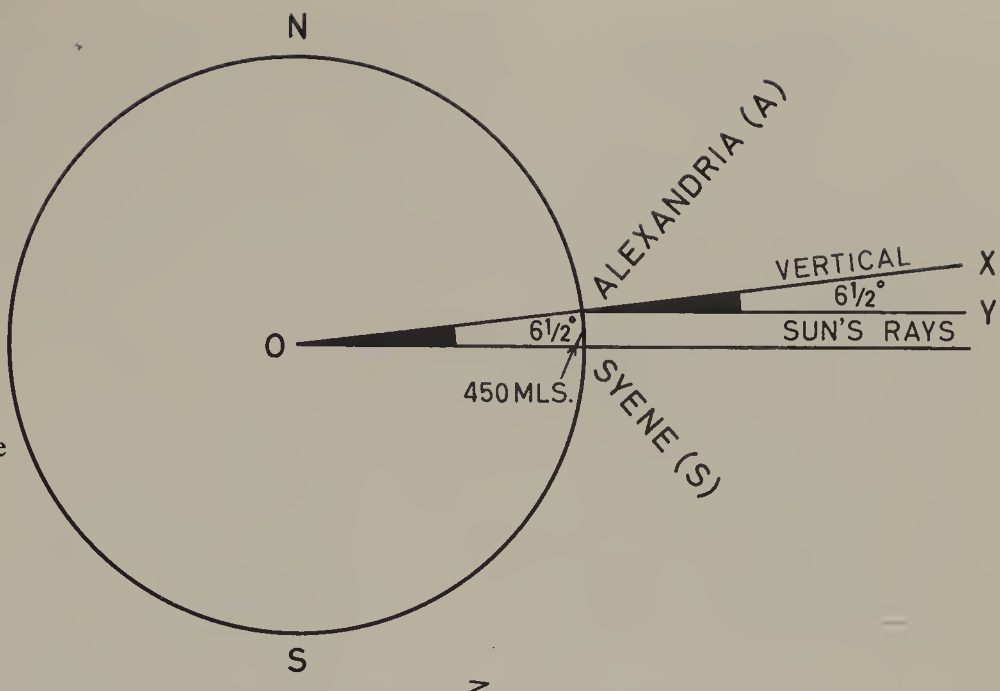
4 When there is an eclipse of the moon the shadow of the earth which is thrown on the moon is always circular.

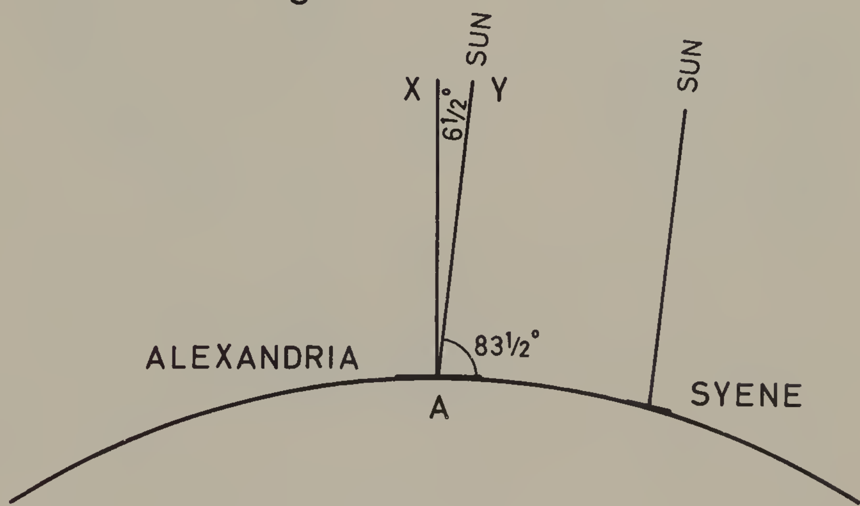
5 It is possible to circumnavigate the earth by air in any direction.

6 Pictures taken from rockets at great heights clearly show the curvature of the earth.

The Size of the Earth

About 200 B.C. Eratosthenes measured the altitude of the midday sun at Alexandria and found that it was 83½°. He knew that at the same time on this particular day the altitude of the sun at Syene, which was about 450 miles to the south, was 90°. Eratosthenes knew that angle XAY was 6½° and that angle AOS was also 6½°. He then calculated that if an angle of 6½° is subtended by an arc of 450 miles then an angle of 360° would be subtended by an arc of 25,000 miles.





The Position of a Place on the Earth's Surface

Let us take a large ball and mark two points on it so that they are exactly opposite to each other. Now draw a line right round the ball so that it is midway between the points all the way. The line will now divide the ball into two equal parts, and, because the ball is a sphere, each part can be called a *hemisphere*. We will now call the line the *equator* and you will see that it is a *circle*. One point we will call the *North Pole* and the other the *South Pole* (*fig. a*).

We can now draw more circles parallel to and to the north and south of the equator. These can be called *parallels* or lines of latitude (*latitude* referring to the angular distance north or south of the equator). This idea is applied to the earth. The equator is given a value of 0°, and, as you can see from *fig. b*, the north pole has a latitude of 90°N. The south pole has a value of 90°S and every other place on the earth's surface has a latitude of so many degrees north or south (of the equator). You will also notice that the equator is the longest parallel. *Figs. c* and *f* show what the parallels look like on a globe from the side and from the pole respectively.

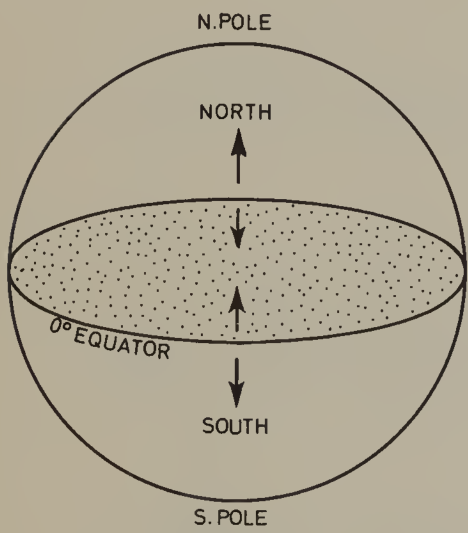


Fig. a

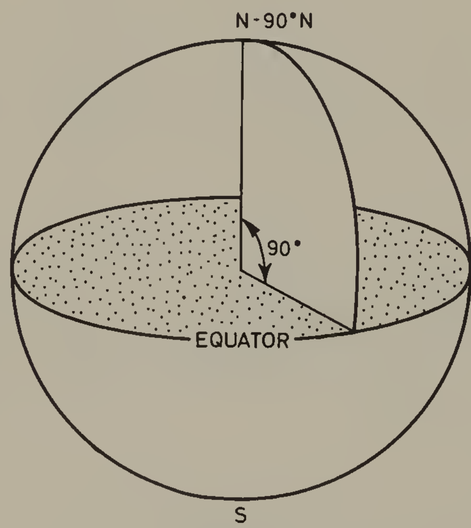


Fig. b

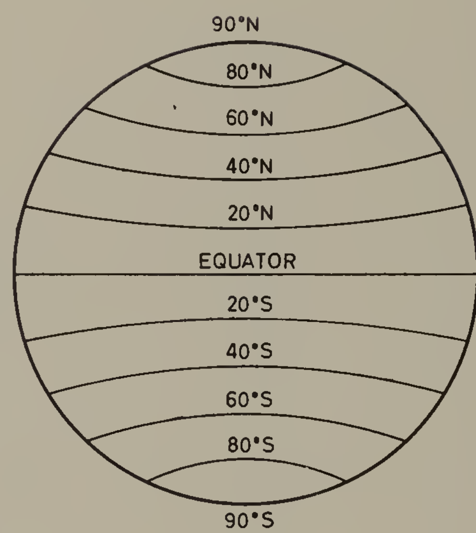


Fig. c

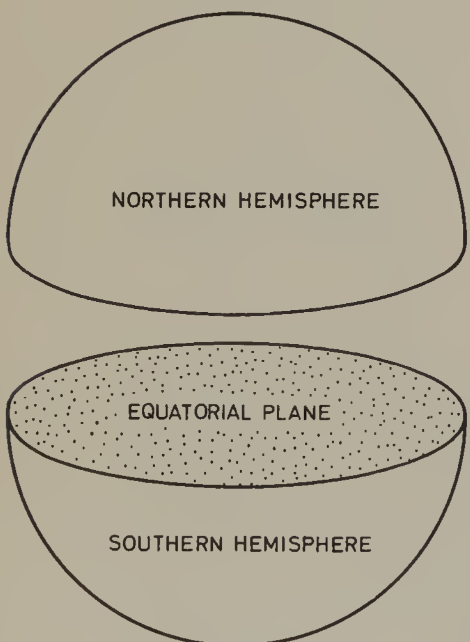


Fig. d

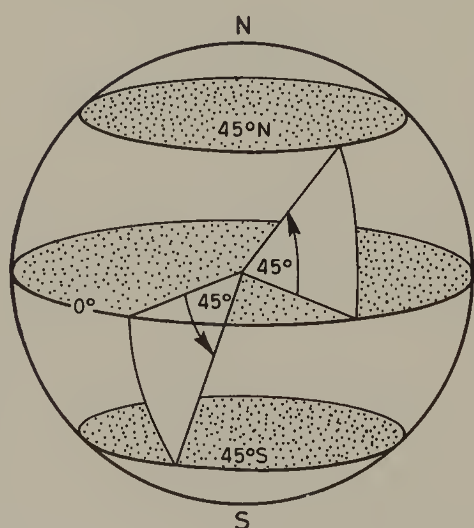


Fig. e

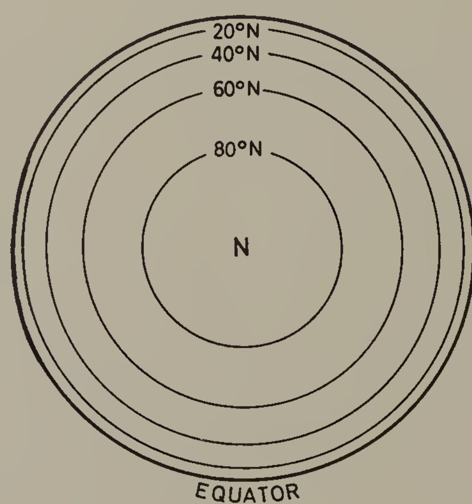


Fig. f

We can now draw on the ball another set of circles all of which pass through the two poles (*fig. k*). That part of each circle between the poles can be called a *meridian* or line of *longitude.* This idea is also applied to the earth and the meridian which passes through Greenwich is given a value of 0°; the meridian that is opposite to it will therefore have a value of 180° (*fig. g*). Longitude refers to the angular distance east or west of the Greenwich Meridian, and all places except those on meridian 180 will therefore have a longitude of so many degrees east or west (of Greenwich). *Figs. k* and *l* show what the meridians look like from the side and from the pole respectively.

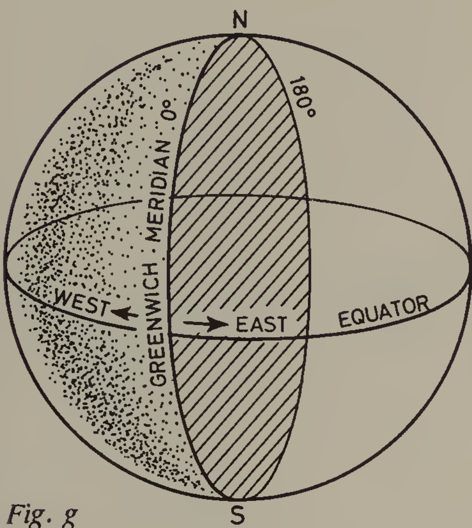


Fig. g

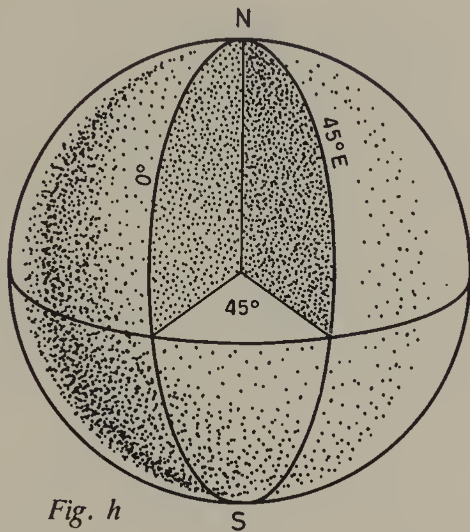


Fig. h

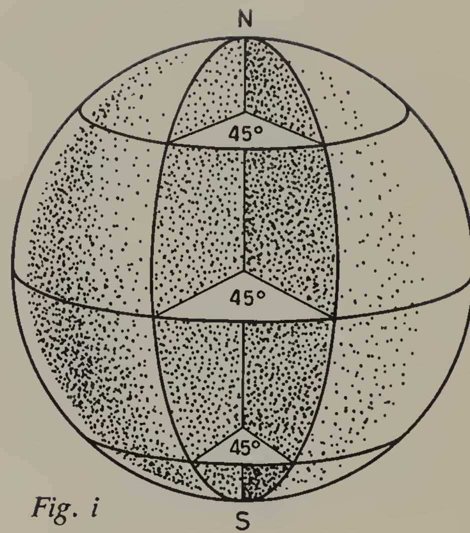


Fig. i

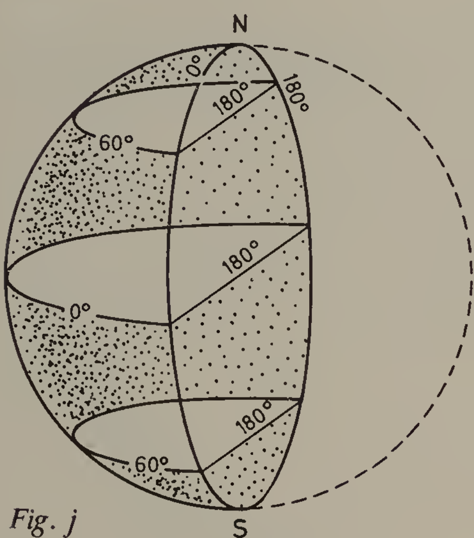


Fig. j

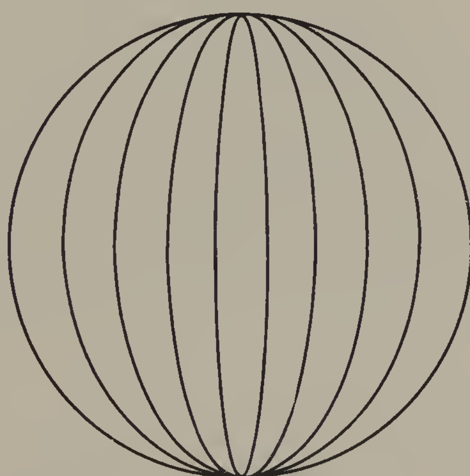


Fig. k

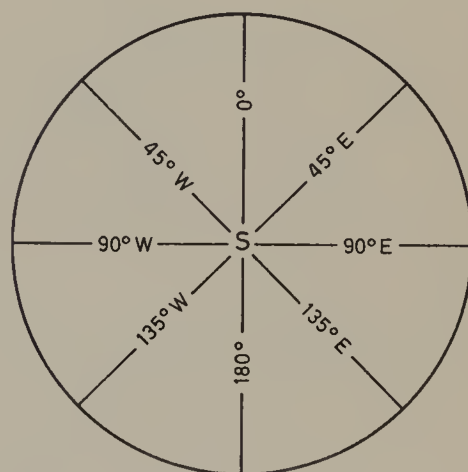


Fig. l

How long is 1° of Latitude?

Fig. m is a diagram of a hemisphere and N and S stand for the north and south poles. Angle NOA is 90° and this is the latitude of N or the angular distance of N from the equator (0°). This angle is subtended by arc NA whose length is one half of a meridian. On the earth arc NA has a length of 6250 miles.

If an arc of 6250 miles subtends 90° then an arc of $\frac{6250}{90}$ miles subtends 1°

i.e. *1° of latitude represents 69.4 miles.*

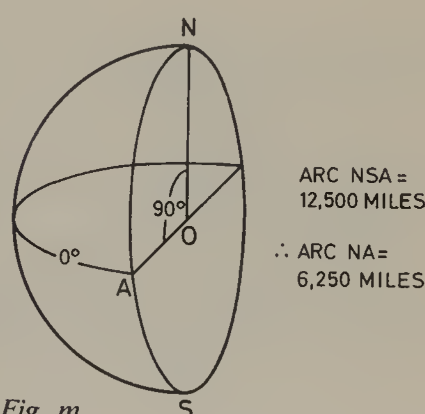


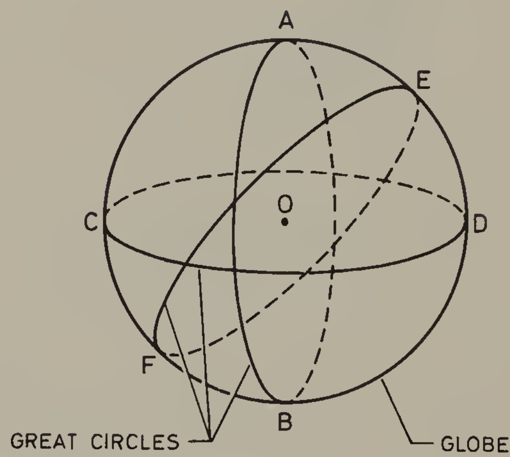
Fig. m

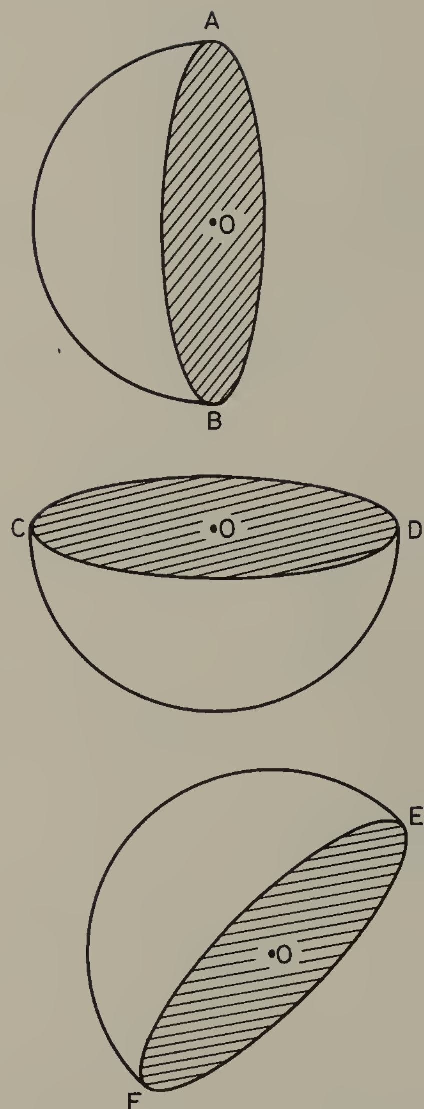
How long is 1° of Longitude?

Every parallel has an angle of 360° at its centre and every half-parallel is subtended by an angle of 180° (*fig. j*, page 5). If the length of the parallel or half-parallel is known then the length of the arc subtended by 1° can be calculated. For the equator this is 69.4 miles, but for other parallels it is less than this because parallels decrease in size away from the equator.
1° of longitude represents 69.4 miles along the equator

Great Circles

Any circle which divides a globe into hemispheres is a *great circle*. The equator is a great circle, and Greenwich Meridian together with meridian 180° make another great circle. Great circles are of equal length. The idea of great circles when applied to the earth is of considerable value to navigation because the shortest distance between two points lies along a great circle.



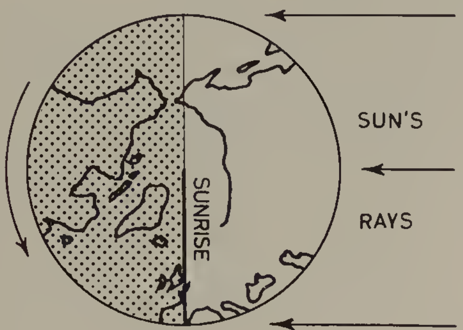


Movements of the Earth

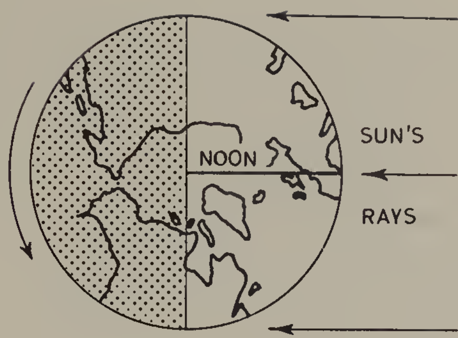
I It rotates II It revolves

Rotation of the Earth
The earth rotates once in 24 hours and this results in:
(i) Day and night
(ii) A difference of 1 hour between two meridians 15° apart
(iii) The deflection of winds and ocean currents
(iv) The daily rising and falling of the tides.

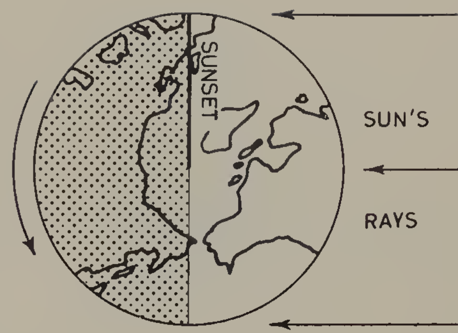
Day and Night
The 4 diagrams below show what is happening along Greenwich meridian during one rotation of the earth on March 21st.



The sun is rising along Greenwich Meridian. People here see it 'rising' over the Eastern Horizon.

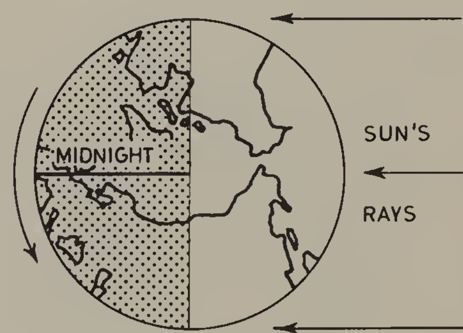


The earth has turned through $\frac{1}{4}$ of a rotation and it is noon along the Meridian. The sun has reached its highest position in the sky.

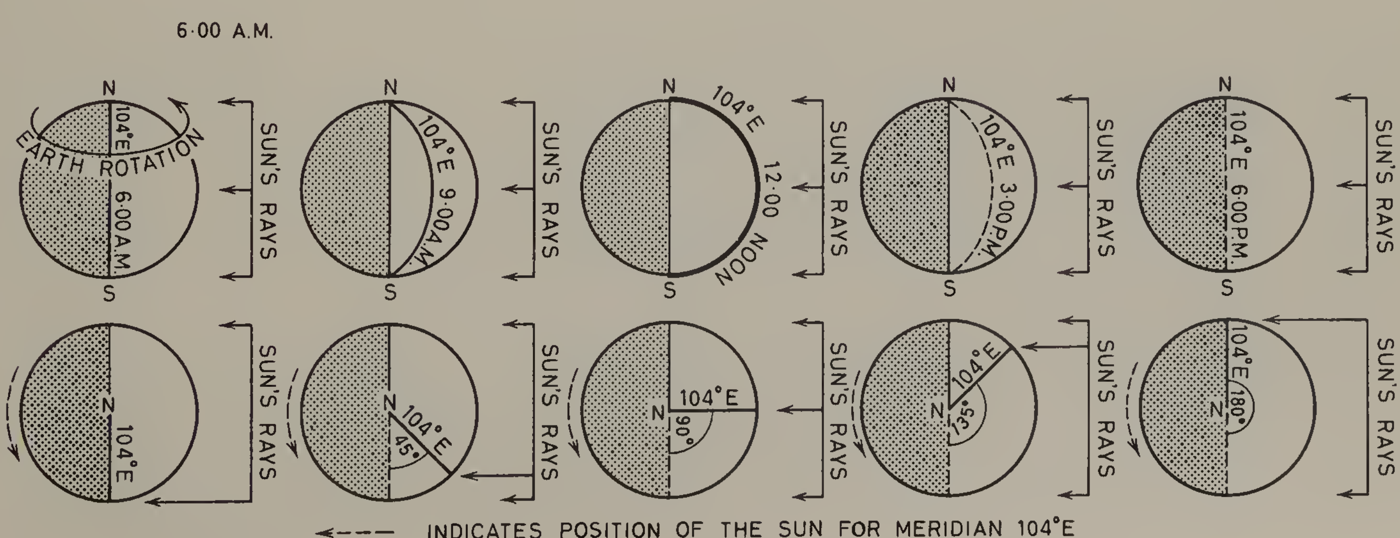


The earth has now turned through $\frac{1}{2}$ of a rotation and the sun is setting along the Meridian. People here see the sun 'sinking' below the Western Horizon.

Rotation and time
The diagram below shows the positions of meridian 104°E at intervals of 3 hours. The top row of diagrams shows the appearance of the meridian from above the equator and the bottom row of diagrams the appearance from above the north pole. The sun reaches its highest position in the sky for this meridian when it lies under the sun. At this time it is said to be *12.00 noon Local Time* along this meridian. Local time is sometimes called *Sun Time*. The highest position of the sun for any place can be observed from a study of the lengths of the shadows cast by a vertical stick. The shortest of these is cast by the sun when it is in its highest position in the sky (study the Sun Path Diagram for Singapore on page 8).

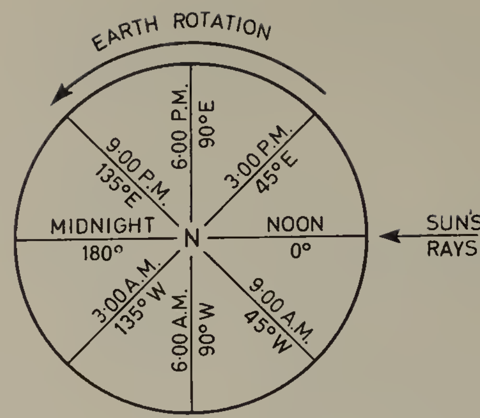


The earth has passed through $\frac{3}{4}$ of a rotation and it is midnight along Greenwich Meridian.



It can be seen from these diagrams that all places on meridian 104°E have sunrise at the same time. This means that *all* these places will have the *same* local time.

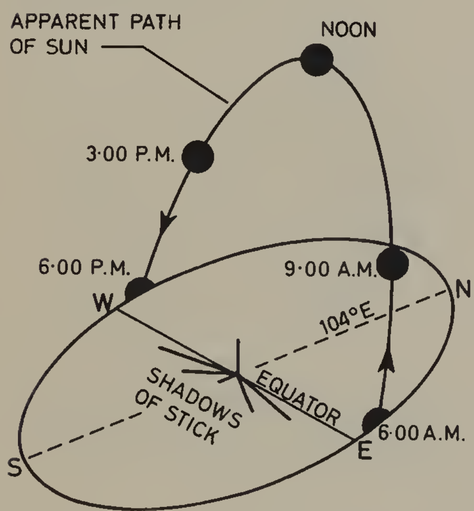
When Greenwich Meridian lies under the sun the local time along this meridian is also 12.00 noon, but this local time is called *Greenwich Mean Time* or G.M.T.



Local times for selected meridians when it is 12.00 noon G.M.T.

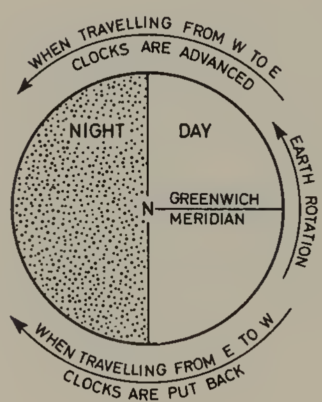
Sun Path Diagram for Singapore on March 21

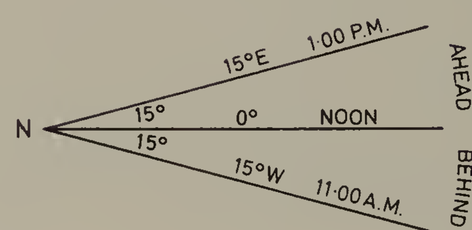
The vertical stick indicates the position of Singapore. The shortest shadow points due south and occurs at *noon*, i.e. when the sun reaches the highest point in its 'path' across the sky.



Behind and Ahead of G.M.T.

All meridians to the east of Greenwich Meridian have sunrise before that meridian. Local times along these meridians are therefore AHEAD of G.M.T. Meridians to the west of Greenwich Meridian have sunrise after this meridian and therefore their local times are BEHIND G.M.T.



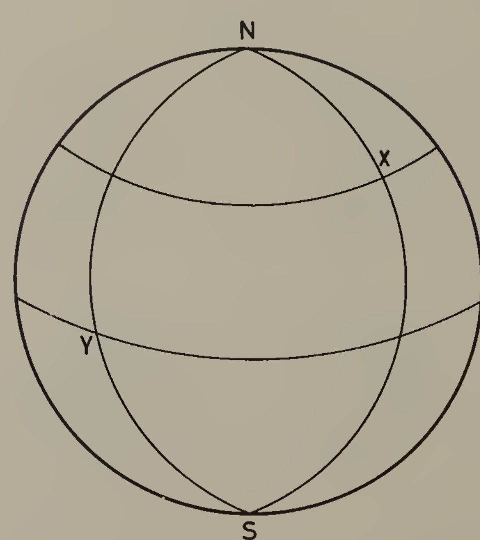


Longitude can be calculated from Local Time and G.M.T.

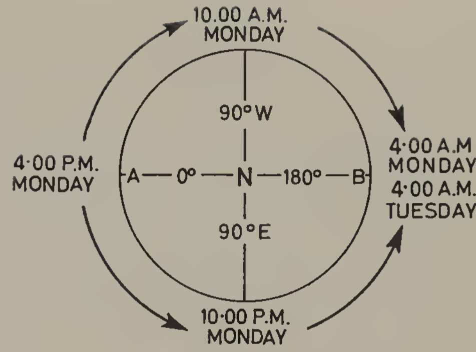
The local time at X is 4.00 p.m. and G.M.T. is 2.00 p.m. The difference in time between X and Greenwich is therefore *2 hours*. This represents a difference of 30° of longitude between the two places (15° of longitude represents 1 hour). Since the local time at X is AHEAD of that at Greenwich then X is EAST of Greenwich. *The longitude of X is 30°E.*

Similarly if the local time at Y is 8.00 a.m. and G.M.T. is 2.00 p.m., then Y is 6 hours BEHIND Greenwich. That is Y is 90° to the WEST of Greenwich and its longitude is 90°W.

Note If any two of the above three facts are given, the third can always be calculated.

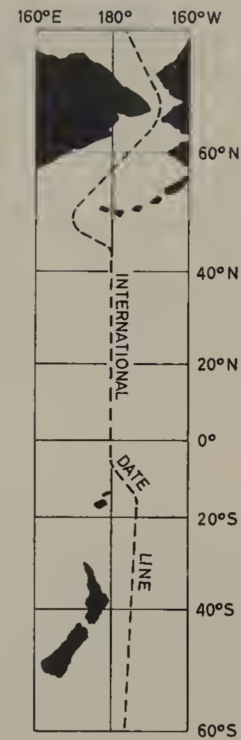


The Significance of the International Date Line



The diagram on the right shows what happens when two travellers set off at the same time (4.00 p.m.) on a Monday from a place A (long. 0°). One traveller goes westwards and the other eastwards to a place B (long. 180°). The traveller going west calculates the local times at 90°W. and 180° to be 10.00 a.m. Monday and 4.00 a.m. Monday respectively. The traveller going east calculates the local times at 90°E. and 180° to be 10.00 p.m. Monday and 4.00 a.m. Tuesday respectively.

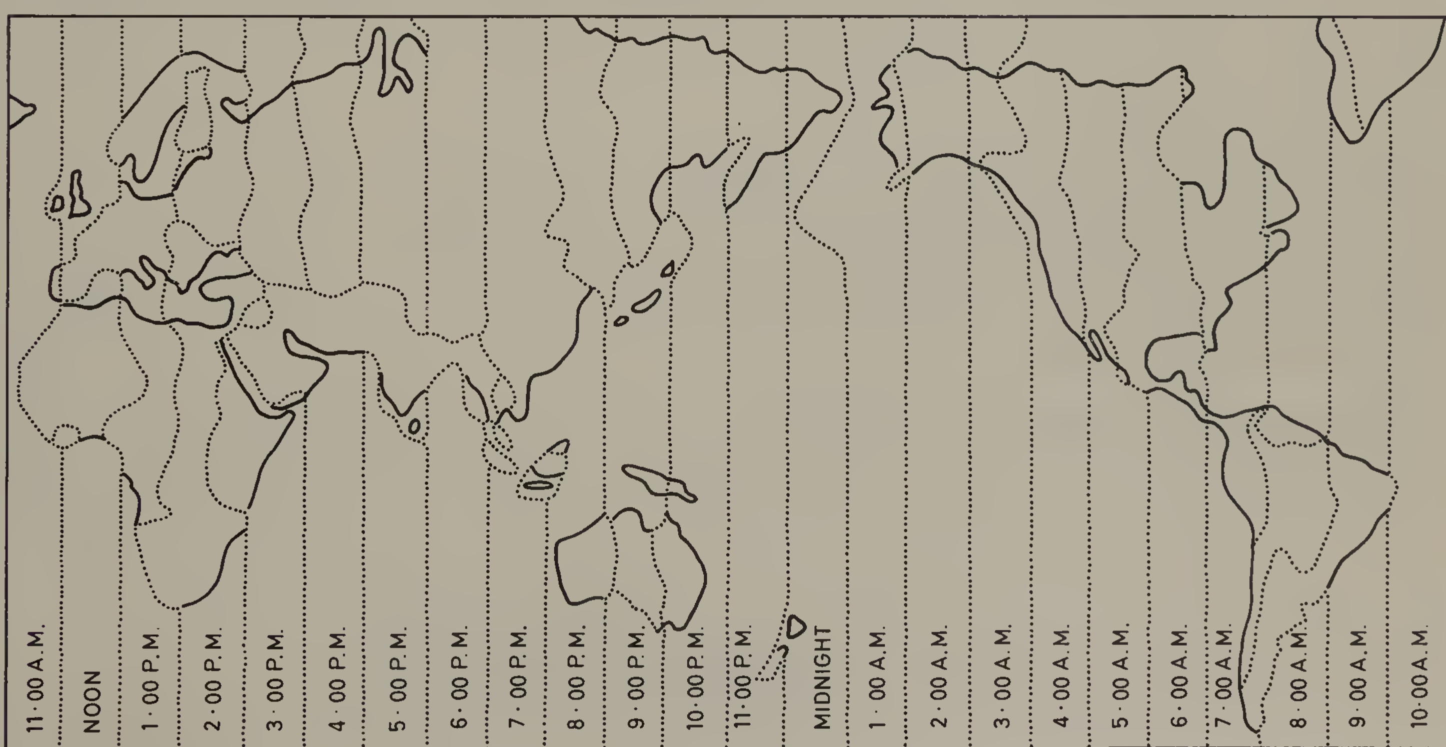
In theory along meridian 180° it is both 4.00 a.m. Monday and 4.00 a.m. Tuesday. When the traveller going west crosses this meridian he finds it is 4.00 a.m. *Tuesday*, i.e. he has *lost one day*. When the traveller going east crosses this meridian he finds it is 4.00 a.m. Monday, i.e. he has *gained one day*.



The line at which a day is lost or gained is called the INTERNATIONAL DATE LINE. This line follows meridian 180° except where this crosses land surfaces. To avoid confusion to the peoples of these regions the line bends round them so passing over a sea surface.

Standard Time and Time Zones

Each meridian has its own local time. Thus when it is 12.00 noon local time in Georgetown (Penang) which is 100° 20′E. it is 12.14 p.m. local time in Singapore whose longitude is 103° 50′E. Great confusion would arise if all places used local time. To avoid this the world is divided into 24 belts, each 15° of longitude wide. The local time of the central meridian of each belt is applied to that belt which is called a *time zone*. The local time of the central meridian for each time zone is called *standard time*. Neighbouring time zones have a difference of 1 hour. The boundaries of time zones are frequently adjusted to conform to political boundaries.



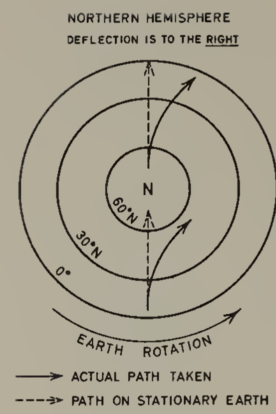
Deflection of Winds and Ocean Currents

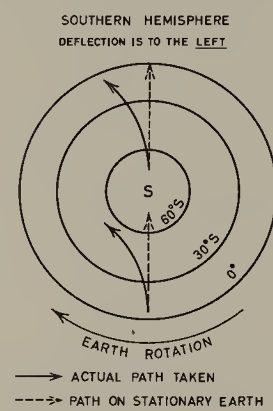
All places on the Earth's surface make 1 revolution in 24 hours. A place on the equator moves eastwards at a greater velocity than a place on say parallel 60°N. because the equator is longer than this parallel. A mass of air or water on parallel 60°N. will have an eastward speed equal to that of the parallel. If this mass moves towards the equator it will cross over parallels whose eastward speeds increase with decreasing latitude. The path of the mass when plotted appears as a curve which bends to the *right* (from the starting point) of the path it would have taken if the Earth had not been rotating.

If a similar air or water mass had moved from a high latitude to a low latitude in the Southern Hemisphere its path would appear as a curve to the *left* of the path it would have taken if the Earth had not been rotating. This can be summarised by stating that in the N. Hemisphere winds and currents are deflected to the RIGHT whilst in the S. Hemisphere they are deflected to the LEFT.

The figure at the top shows deflection to the right of an air or water mass moving (i) towards the pole, and (ii) towards the equator.

The figure on the right shows deflection of an air or water mass moving (i) towards the pole, and (ii) towards the equator.



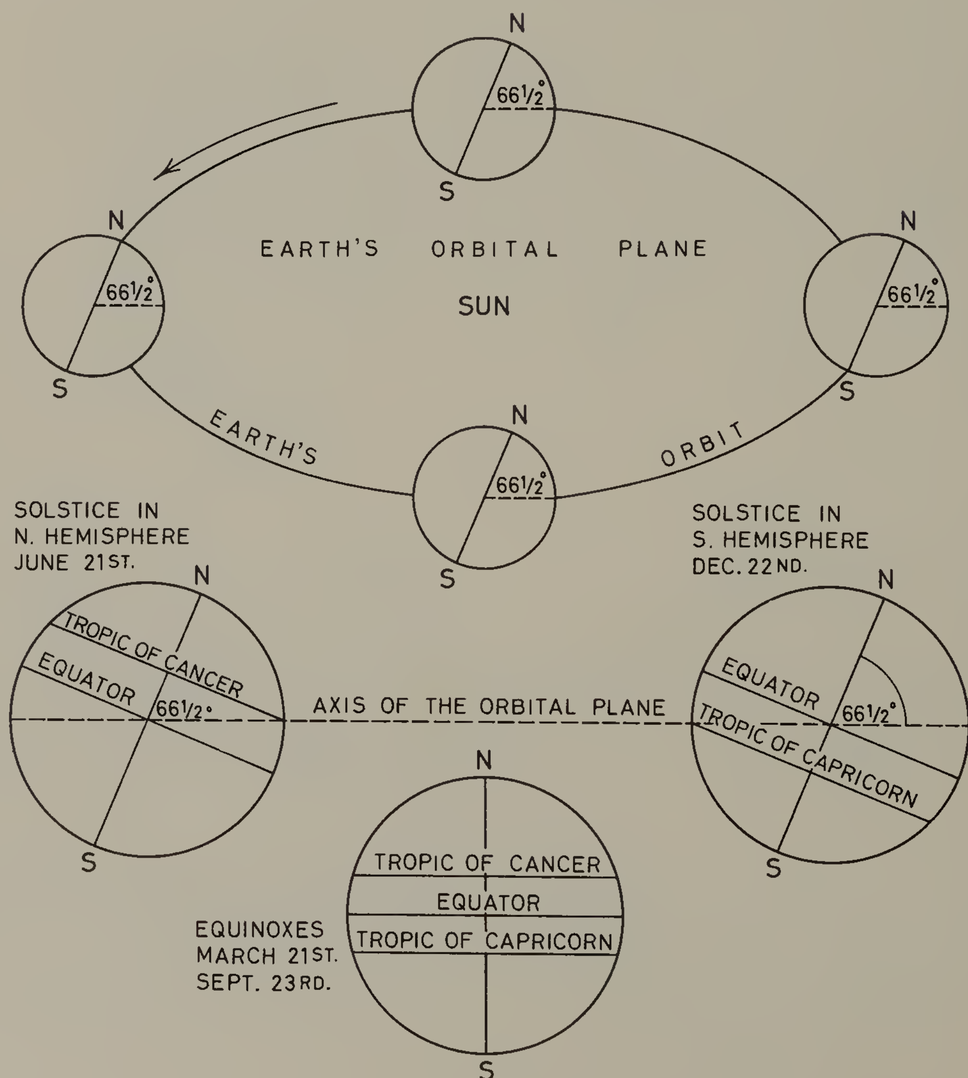


Revolution of the Earth

The Earth takes 365¼ days to revolve once round the Sun. Every fourth year is given 366 days and this is called a *leap year*. All other years have 365 days.

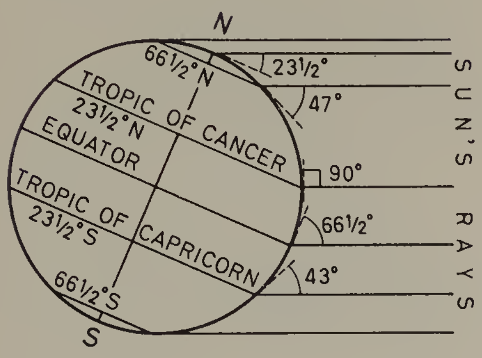
The Earth's axis always points in the same direction in the sky, i.e. to the Pole Star. It is also permanently tilted at an angle of 66½° to the Earth's Orbital Plane. The revolution of the Earth and the inclination of its axis result in:

1 Changes in the altitude of the midday Sun at different times of the year.
2 Varying lengths of day and night at different times of the year.
3 The four seasons.

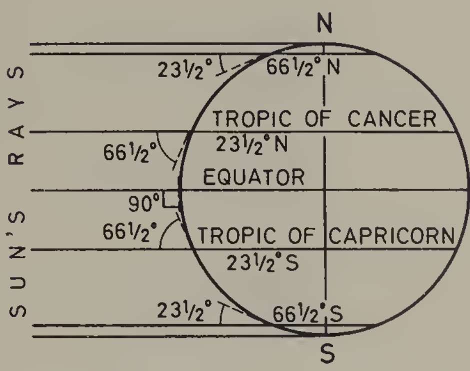


I Changing Altitudes of the Midday Sun at Different Times of the Year

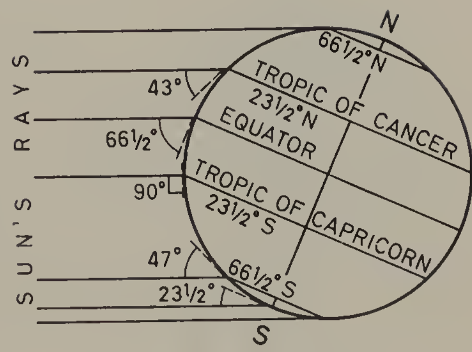
Summer solstice June 21



Equinoxes Mar. 21, Sept. 23

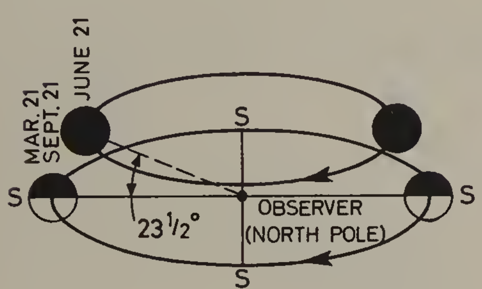


Winter solstice Dec. 22



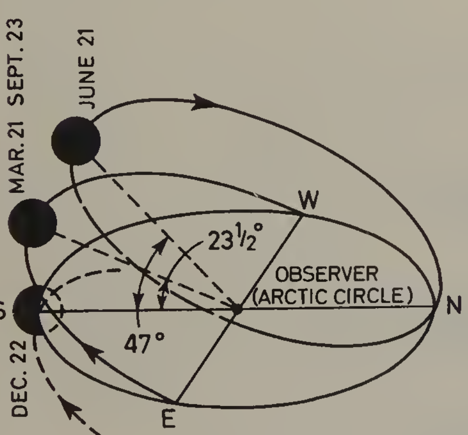
The apparent path of the Sun between sunrise and sunset for selected latitudes during the solstices and the equinoxes

(I) NORTH POLE



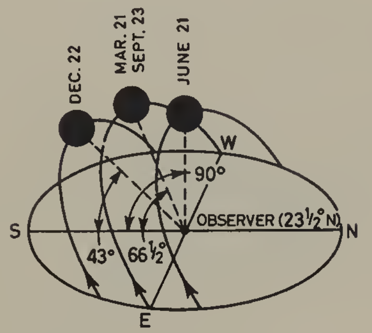
March 21	Sun circles the Pole, one half of it being visible above the horizon.
June 21	After March 21 the Sun rises higher in sky and is visible 24 hours each day. Highest altitude of Sun is on June 21.
Sept. 23	Sun's path the same as for March 21. Sun is visible from March 21 to Sept. 23.
Dec. 22	After Sept. 23 the Sun is not visible above the horizon until March 21.

(II) ARCTIC CIRCLE



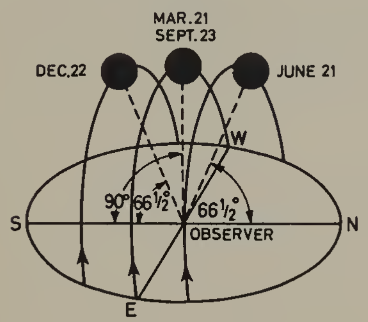
March 21	Sun rises due east and sets due west. It is visible for 12 hours.
June 21	Sun is visible for 24 hours.
Sept. 23	The Sun rises and sets as for March 21.
Dec. 22	The Sun is only visible for a few minutes when it appears above the southern horizon.

(III) TROPIC OF CANCER



March 21	The Sun rises due east and sets due west. It is visible for 12 hours.
June 21	Sun rises north of east and sets north of west. At noon its altitude is 90°.
Sept. 23	Sun rises and sets as for March 21.
Dec. 22	Sun rises south of east and sets south of west. It is visible for less than 12 hours.

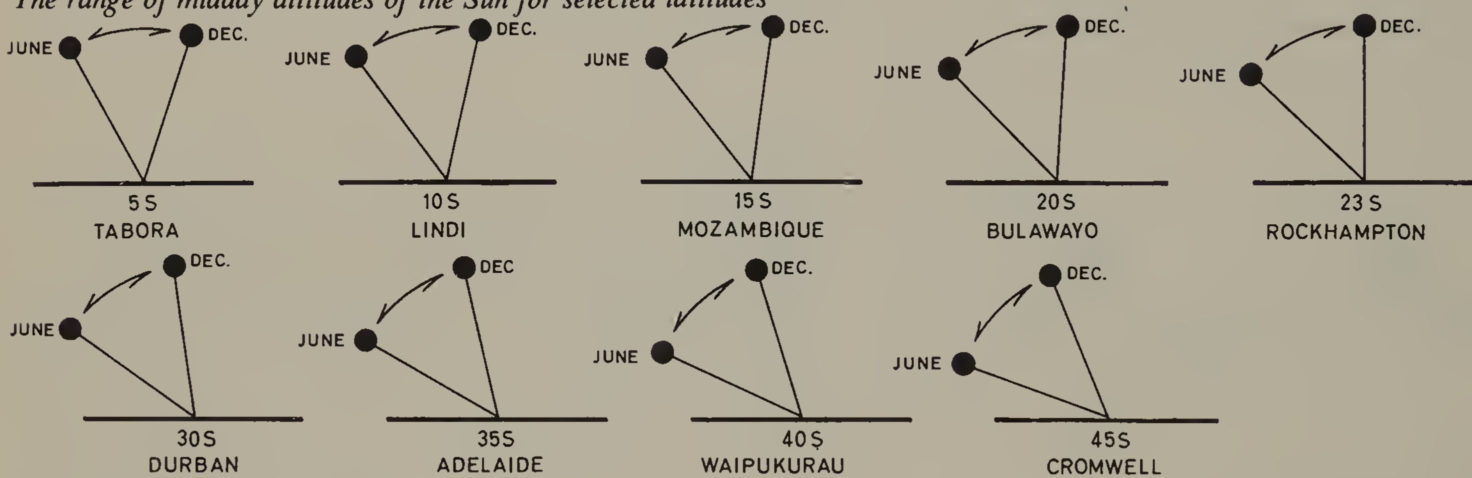
(IV) EQUATOR



March 21	Sun rises due east and sets due west. Midday altitude is 90°.
June 21	Sun rises north of east and sets north of west.
Sept 23	Sun rises and sets as for March 21.
Dec. 22	Sun rises south of east and sets south of west.

Note. The Sun is visible for 12 hours every day of the year.

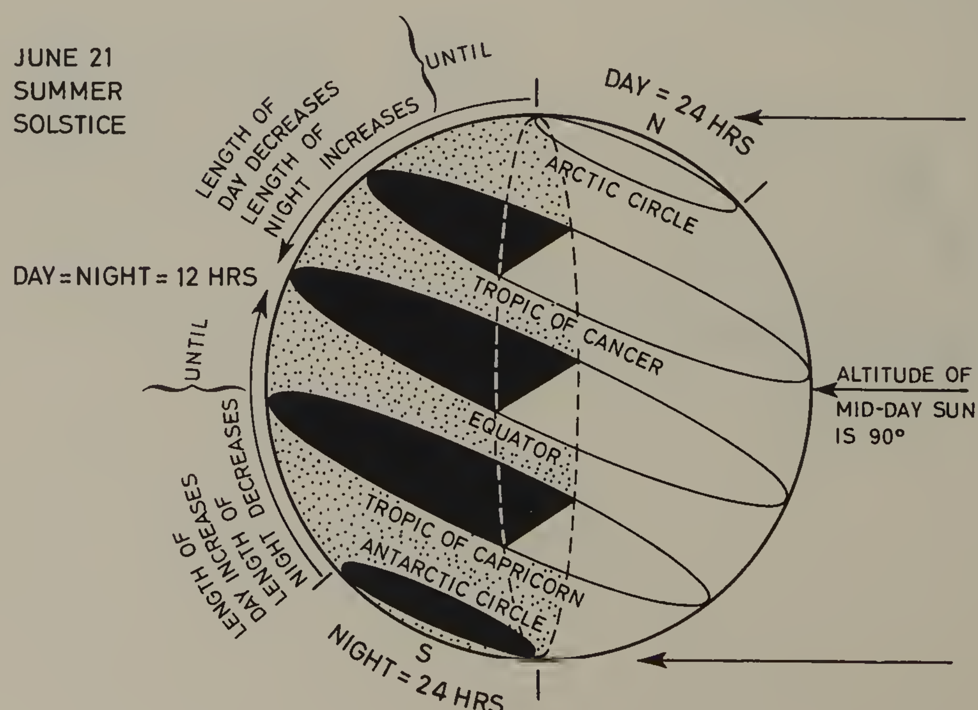
The range of midday altitudes of the Sun for selected latitudes



II The Varying Lengths of Day and Night at Different Times of the Year

The shaded part of each diagram represents night. The lengths of day and night for a selected parallel can be found by comparing that part of the parallel in the shaded zone with that part of it in the non-shaded zone.

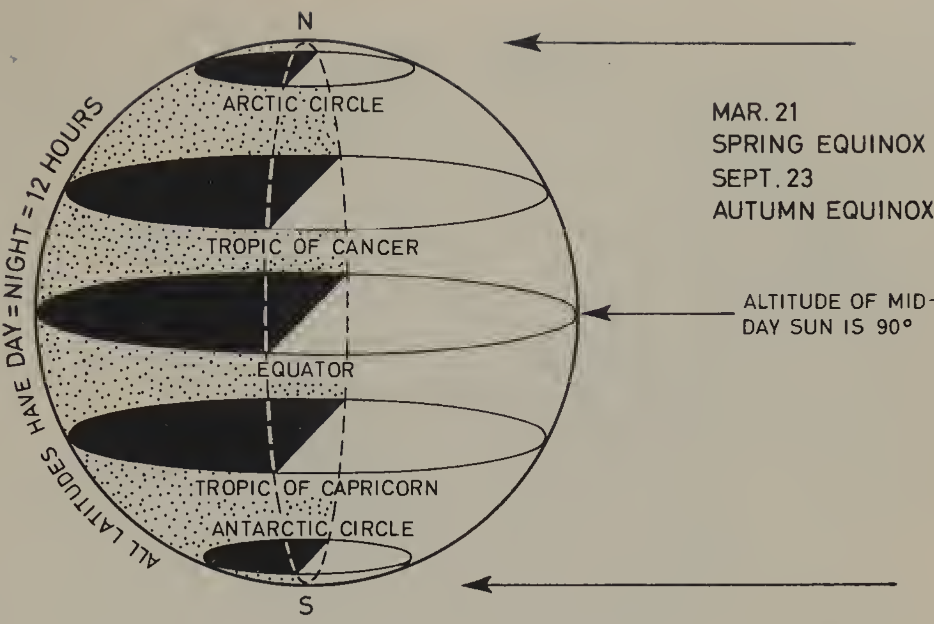
In each diagram one half of the equator has night while the other half has day, i.e. DAY = NIGHT along the equator throughout the year.

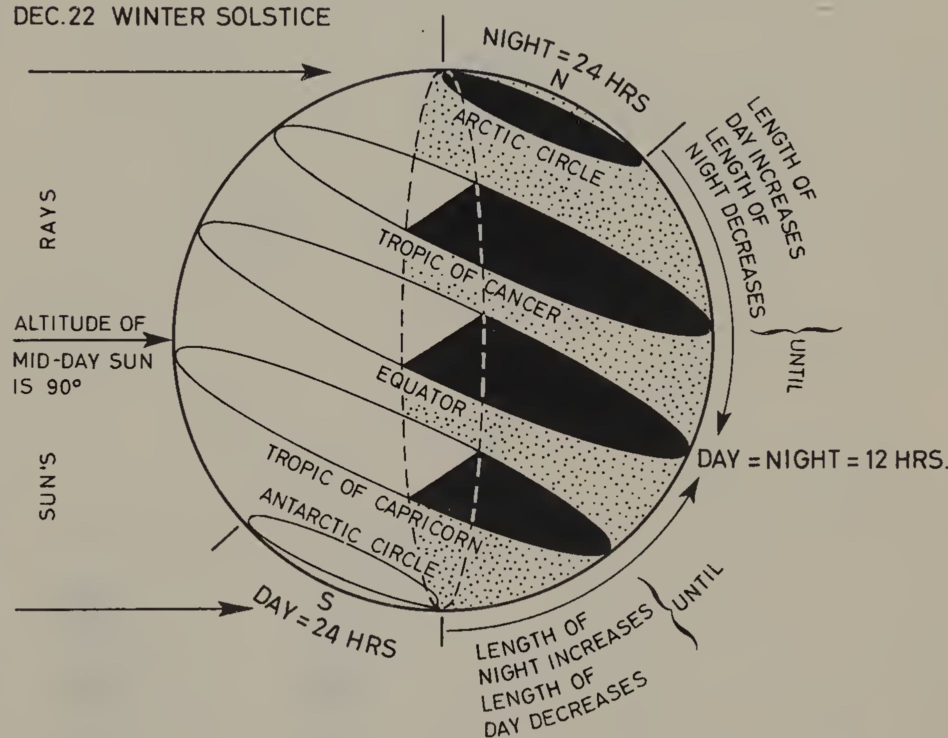


Throughout the year one half of the Earth has day while the other half has night. Only during the Equinoxes does the dividing line between day and night coincide with meridians (see diagram). During the Equinoxes the Sun is overhead at noon along the equator and at these times (March 21 and September 23) DAY = NIGHT along every parallel.

On June 21 the Sun is overhead at noon along the Tropic of Cancer and all parallels in the Northern Hemisphere have their longest day of the year. At this time the length of the day increases as latitude increases north of the equator until there is continuous day north of the Arctic Circle. South of the equator the length of the day decreases with increasing latitude until there is continuous night south of the Antarctic Circle.

On December 22 the reverse takes place, i.e. the length of the day increases with increasing latitude south of the equator but decreases with increasing latitude north of the equator.

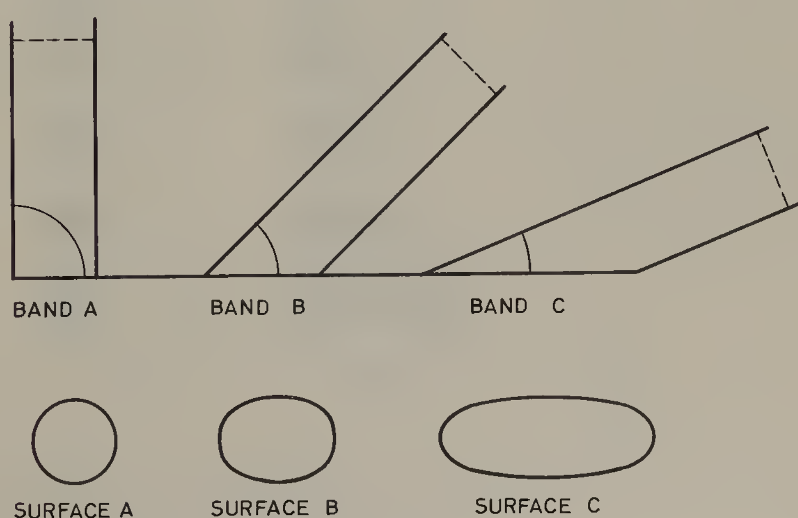




III The Seasons

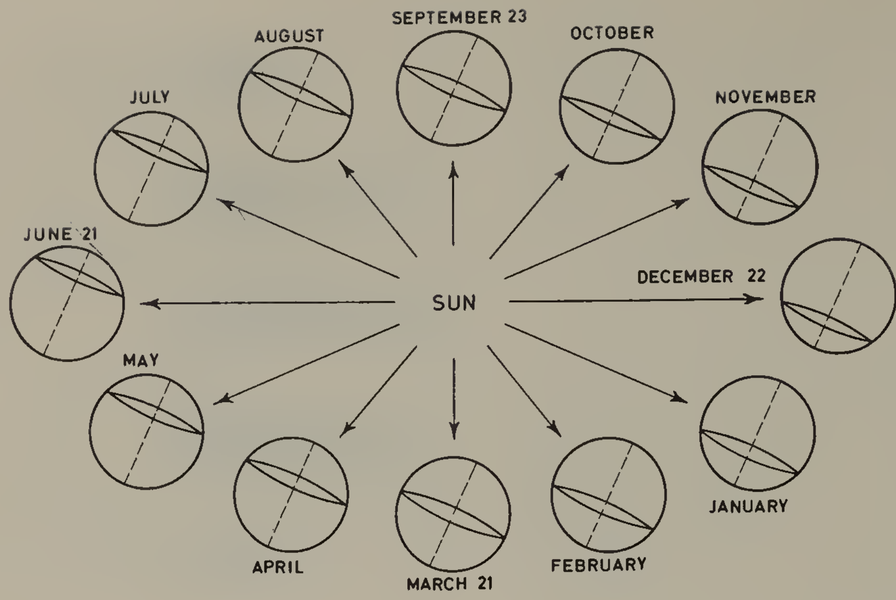
All parts of the Earth's surface except the equatorial latitudes experience a definite rise in temperature during one part of the year and a corresponding fall in temperature during another part of the year. This rise and fall in temperature is chiefly caused by the the varying altitude of the midday sun and the number of hours of daylight. High midday sun altitudes cause high temperatures whereas low midday sun altitudes cause low temperatures.

The diagram on the right shows three bands of light (A, B, C) each containing the same amount of sun energy (this is indicated by equal diameters shown in dotted lines). Band A has its energy spread over Surface A; Band B has its energy spread over Surface B, and Band C has its energy spread over Surface C. Clearly the temperature will be highest at A and lowest at C.



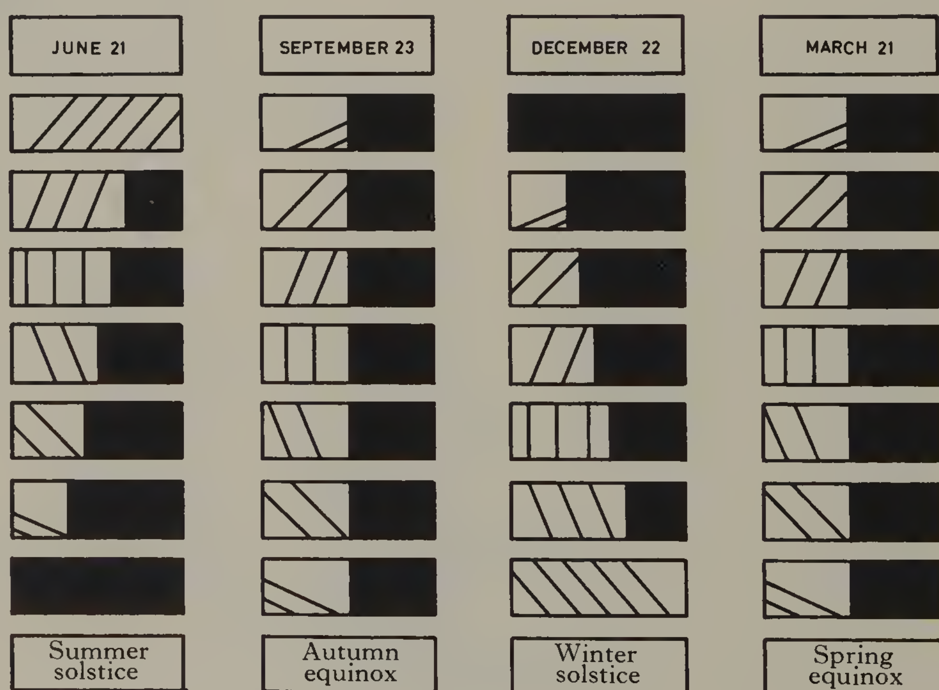
Sun Altitude in relation to Heating

The monthly positions of the Earth in its revolution round the Sun are shown in the diagram on the right. The parallel at which the Sun is overhead at noon is shown for each position. The overhead position of the Sun 'moves' from the equator on March 21 northward to the Tropic of Cancer on June 21, then back to the equator on September 23 and then 'moves' southwards to the Tropic of Capricorn on December 22 and finally returns to the equator on March 21.



Associated with the overhead Sun is a belt of heat and it is the movement of this belt between the Tropics which results in the alternation of the seasons. The Northern Hemisphere receives its maximum amount of solar radiation during June and its minimum amount during December (diagrams at bottom of page 12 and middle of page 13). Between March 21 and September 23 this hemisphere has its summer while between September 23 and March 21 it has its winter. Spring and Autumn are two shorter seasons which occur between the two main seasons and which represent a transition from one to the other.

The relationship between length of day, latitude and time of year is shown in the diagram on the right. Also shown is the altitude of the midday Sun for each latitude. Notice how the length of day decreases from a maximum at 66½°N to a minimum at 66½°S on June 21, and how it increases from a minimum at 66½°N to a maximum at 66½°S on December 22. Finally notice how all latitudes have day equal to night at the equinoxes and how day always equals night along the equator.



Each rectangle represents 24 hours. Night is shaded and day is left white. The lines represent the altitude of the Sun at midday.

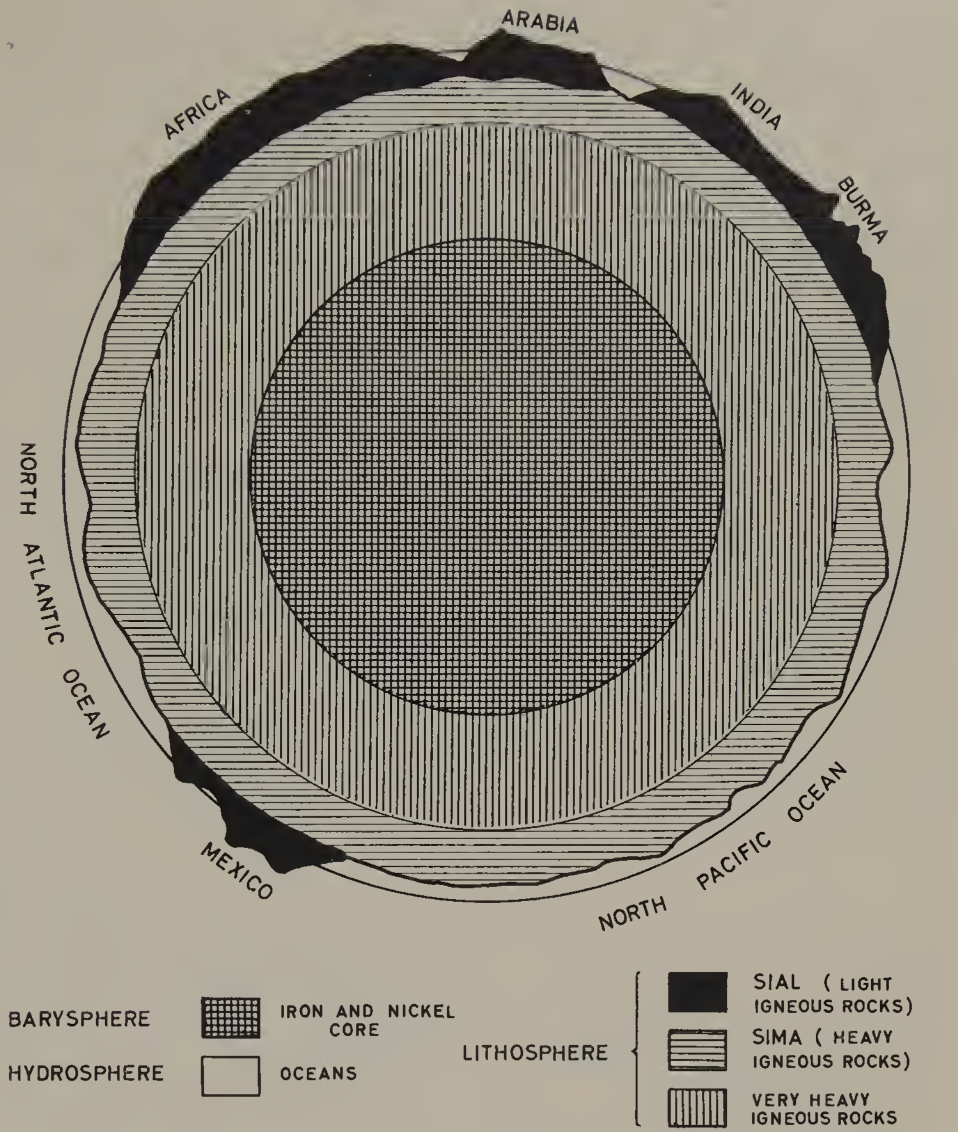
Structure of the Earth

Beneath the soil and the sedimentary rocks of the land masses are layers of rocks rich in *silica* and *alumina* (see below). These are collectively called the SIAL. The sial is thus the continental crust.

Below the sial and also forming the foundations of the ocean floors are layers of rock rich in *silica* and *magnesia* (see below). These are collectively called the SIMA. Rocks of the sial are much lighter than those of the sima and hence the continents can be regarded as 'floating' on a sea of sima.

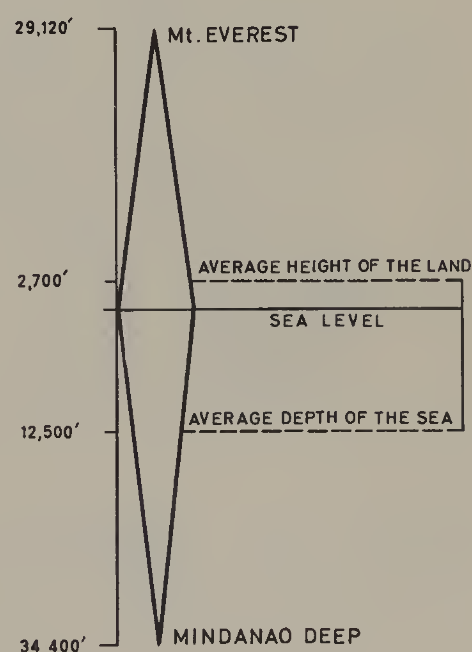
Lying beneath the sima are rocks of a mixed nature of even greater weight than those of the sima. These rocks plus the sima and the sial are known as the LITHOSPHERE, or the EARTH'S CRUST, and it has a depth of between 500 and 1,000 miles.

The interior of the Earth is occupied by a core of rocks rich in iron and nickel and it is called the BARYSPHERE. The HYDROSPHERE refers to the water masses (oceans and seas, etc.) on the surface. The ATMOSPHERE is composed of a mixture of gases which forms an envelope round the Earth.

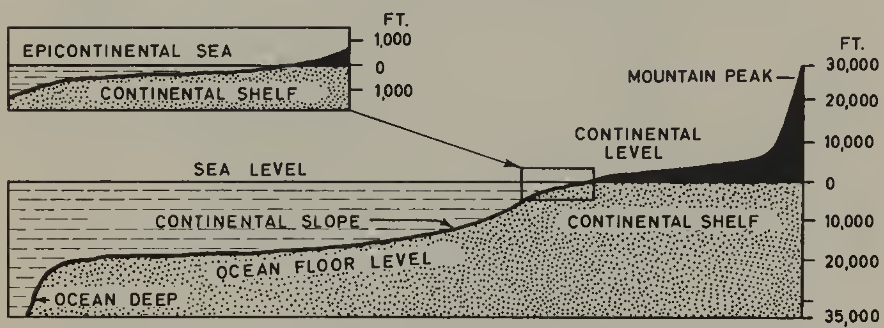


Distribution of Land and Water

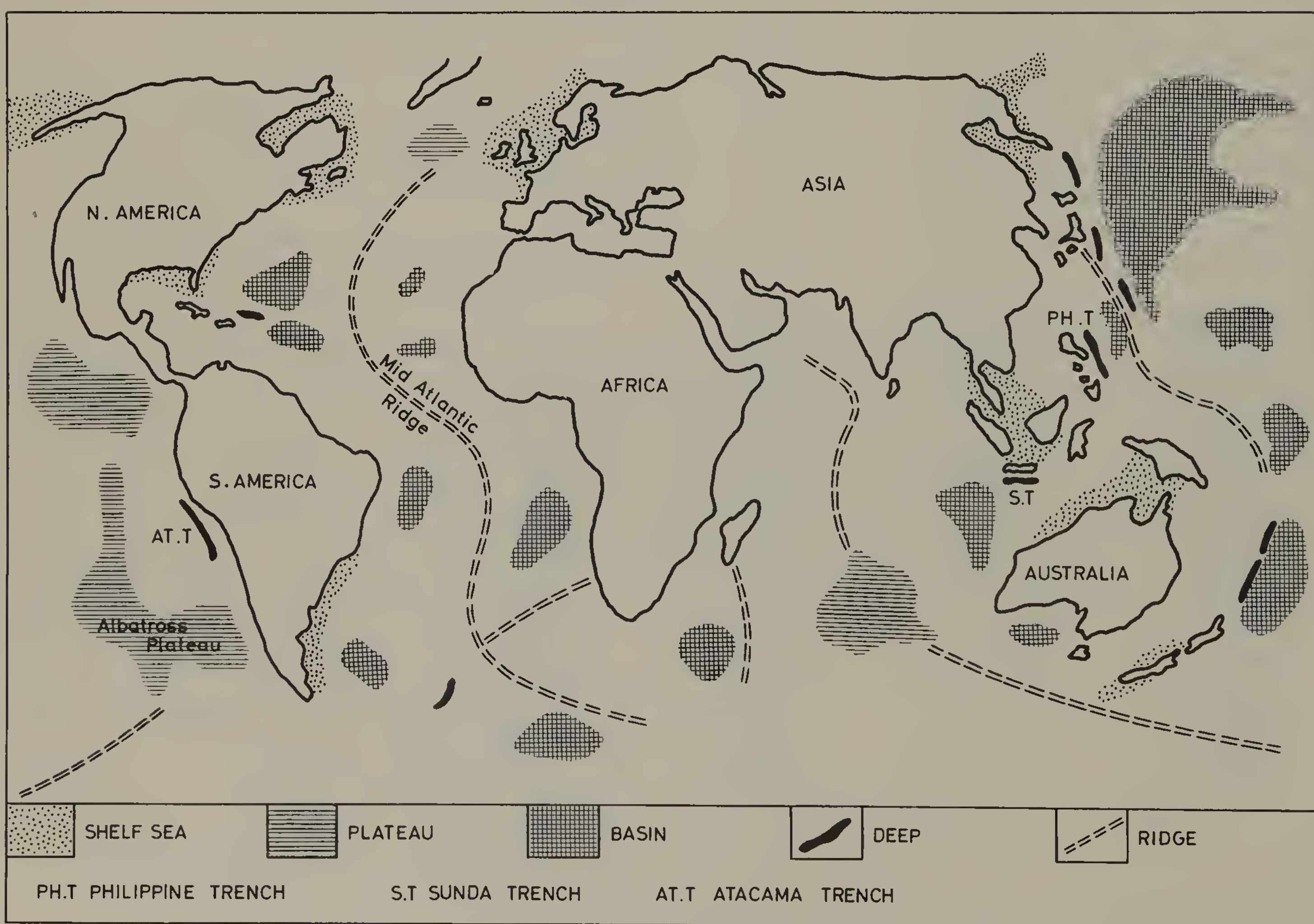
The water surface of the Earth accounts for just over 70% of the Earth's surface. This distribution is not the same for both Northern and Southern Hemispheres. In the latter it is as much as 80% of the total surface area of that hemisphere. The average height of the land is just under 3,000′ while the average depth of the oceans is 12,500′ (diagrams on the left and below). The greatest height is Mt. Everest (29,120′) on the northern border of Nepal, and the greatest depth is the Mindanao Deep (34,400′) off the east coast of the Philippines.



The relationship between land and water surfaces is shown by the diagram below. Two main levels can be recognised: (i) the *ocean floor level*, and (ii) the *continental level*. The two are connected by the *continental slope*. The edge of the continental level is submerged to a depth of about 600′ and this zone is called the *continental shelf*. The seas on this shelf are called *epicontinental* or *shelf seas* (the importance of these is discussed in a later section). The more important of these shelf seas in the Tropics are (i) between N. Australia and New Guinea, (ii) between Borneo and Malaya and Thailand, and (iii) along the Gulf Coast of North America.



The continental surface is broken by mountain ranges, plateaus, and plains, whilst the ocean floors are far from level. Basins and deeps cause the floor to plunge to great depths. Extending across most of the oceans are ridges, some of which rise above the level of the sea to form chains of islands. Extensive plateaus also occur in some oceans.



Rocks and Minerals

The Earth's crust is composed of rocks each of which is made up of minerals. Most minerals are compounds of several elements, e.g. silica (SiO). A few minerals are themselves elements, e.g. carbon (diamond), gold and sulphur. Silica often combines with other oxides to form *silicates*, the most common of which are *felspars*. *Mica* is another common silicate.

Minerals are frequently crystalline, i.e. the atoms forming the crystals are arranged in a definite manner. Some minerals are non-crystalline, i.e. the atoms forming the mineral are not arranged in any definite order.

Felspars are silicates of aluminium (Al), potassium (K), sodium (Na) and calcium (Ca).

Augite, *hornblende* and *olivine* are silicates of iron (Fe), magnesium (Mg), calcium (Ca) and aluminium (Al).

Clay minerals are complex silicates derived from weathered minerals such as felspars. They are silicates of aluminium (Al).

Felspars which weather under tropical humid conditions lose their silica. The residue is chiefly oxides of aluminium and these are called *bauxite*.

Classification of Rocks according to origin

IGNEOUS	Have originated below the Earth's crust
SEDIMENTARY	Made from rock particles deposited by wind, water or ice
METAMORPHIC	Formed from any rock subjected to great pressure and heat
ORGANIC	Formed from plant and animal remains
CHEMICALLY-FORMED	Formed by the evaporation of water from solutions containing minerals.

Igneous Rocks

I *Volcanic* (poured out onto Earth's surface)
e.g. *basalt*

II *Plutonic* (solidified deep in Earth's crust reaching the surface only through erosion)
e.g. *granite*

Chemically-formed Rocks

e.g. certain *limestones*, *salt*, *nitrates*, *borax*

Sedimentary Rocks

I *Wind-deposited*
e.g. *loess*

II *River-deposited*
e.g. *clays*, *gravels* and *alluviums*

III *Glacier-deposited*
e.g. *moraines*, *sands* and *gravels*, *boulder clay*

IV *Sea-deposited* (very similar to those of II)

Metamorphic Rocks

When a rock is metamorphosed its texture and appearance change entirely, e.g.
marble (from limestone)
slate (from clay)
gneiss (from granite)
quartzite (from sand)

Organic Rocks

I *From animals*, e.g.
chalk and *coral*

II *From plants*, e.g.
peat, *coal*, *lignite*

Grouping of sedimentary rocks according to their texture

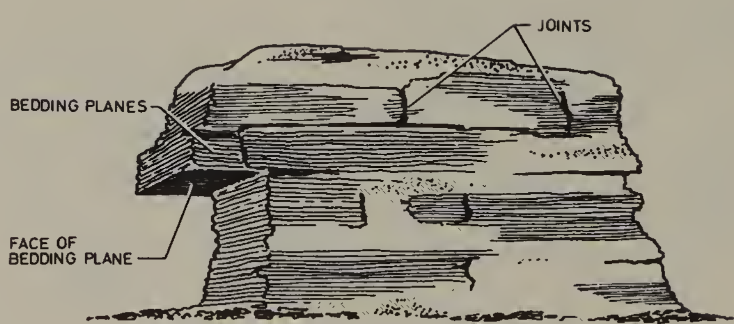
CLAYS	Composed of microscopically fine particles
SILTS	Composed of particles not quite so fine
SANDS	Composed of coarser particles (easily seen with the naked eye). When cemented together they form *sandstones* (these are called *grits* when the sand grains are angular)
GRAVELS	Composed of rounded and large particles. When cemented together they form *conglomerates*
BRECCIA	Composed of coarse and angular particles which have been cemented together

Joints

Rocks very often develop cracks when they are subjected to strain produced by compression or tension. The strain may be caused by Earth movements, or by contraction when molten rocks solidify, or by the shrinking of sedimentary rocks on drying. The cracks so formed are called *joints*. In sedimentary rocks joints are often at right angles to the bedding plane. Sometimes more than one set of joints develops. When this happens the rock becomes broken into blocks, e.g. limestone and sandstone, or into columns as in some lavas, e.g. basalt.

Note Jointing does not result in the displacement of rocks as does faulting (see pages 21 and 25).

Joints in granite in South-west England



SANDSTONE CLIFF SHOWING BEDDING PLANES

The Forces which Produce Physical Features

A. **Internal** (operate within the Earth's crust)

I *Earth Movements*

(i) *Vertical* (up and down) movements cause faulting of the crustal rocks. Features produced: *plateaus*; *block mountains* (horsts); *basins*

(ii) *Lateral* (sideways) movements cause folding of the crustal rocks. Features produced: *fold mountains*; *rift valleys*; *horsts*, *block mountains*

II *Volcanic Eruptions*

(i) *External* (lavas reach the Earth's surface). Features produced: *lava plains and plateaus*; *volcanic cones*; *geysers*

(ii) *Internal* (lavas solidify in the crust). Features produced: *dykes*; *sills*; *batholiths*; *laccoliths*

B. **External** (operate on the Earth's surface)

I *Denudation*

(i) *Weathering* (the break-up of rocks by alternate heating and cooling; chemical actions; and the action of living organisms). Features produced: *soil*; *earth pillars*; *screes*

(ii) *Erosion* (the break-up of rocks by the action of rock particles being moved over the Earth's surface by water, wind and ice). Features produced: *valleys*; *peneplains*; *cliffs*; *river* and *coastal terraces*; *escarpments*

(iii) *Transport* (the movement of rock particles over the Earth's surface by water, wind and ice)

II *Deposition*

(i) *By Water* (river or sea). Features produced: *flood plains*; *levees*; *alluvial fans*; *deltas*; *beaches*; *lake plains*; *marine alluvial plains*

(ii) *By Ice* (ice sheets and valley glaciers). Features produced: *boulder clay plains*; *outwash plains*; *moraines*; *drumlins*; *eskers*

(iii) *By Wind* Features produced: *loess plains*; *sand dunes*

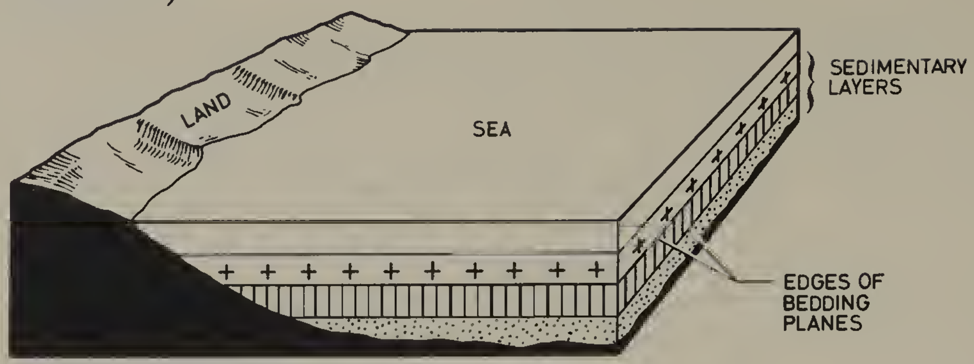
(iv) *By Living Organisms* (e.g. coral) Features produced: *coral formations*

(v) *By Evaporation and Precipitation* Features produced: *salt deposits*

(vi) *Of Organic Matter* Features produced: *coal deposits*

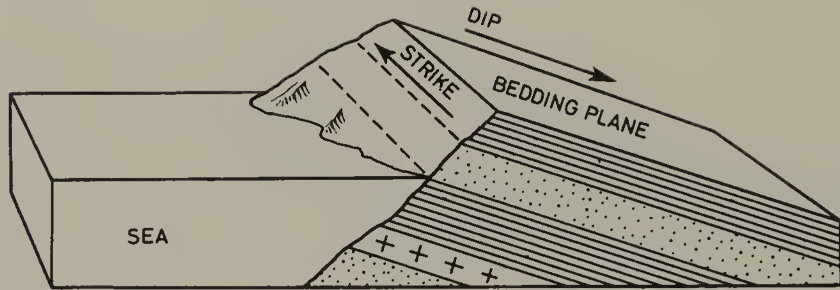
Chapter 2 Internal Forces
(earth movements)

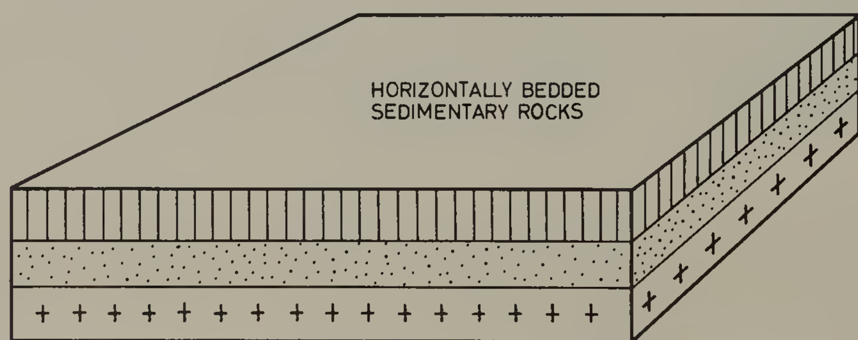
Sedimentary rocks are formed from sediments which have been laid down in horizontal layers. This layering is called *stratification*, and sedimentary rocks are therefore *stratified rocks*. The face of each layer is called the *bedding plane*.

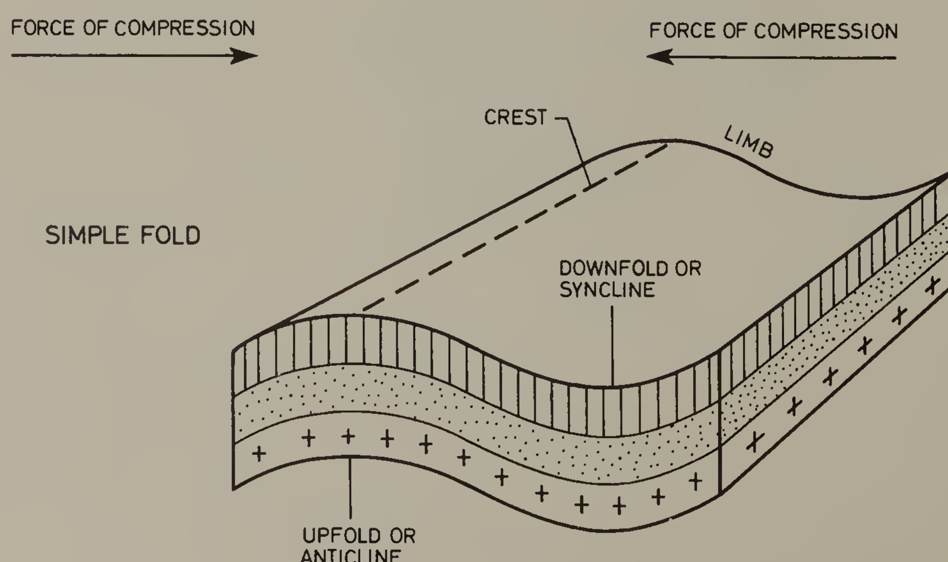


Earth movements cause sedimentary rocks to be displaced, i.e. to be pushed out of the horizontal plane so that the rocks are tilted or inclined. The inclination of the rocks is called the *dip*. The direction parallel to the bedding plane and at right angles to the dip is called the *strike*. The second diagram on the right has had the upper sedimentary layer removed so as to show the bedding plane, dip and strike.

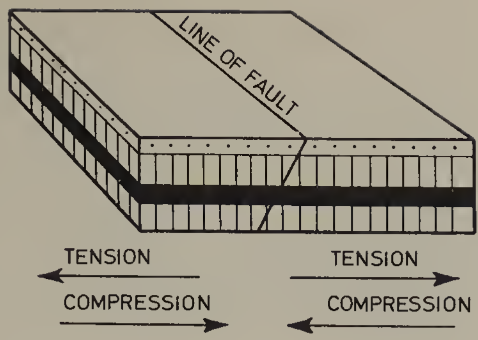
Earth movements can also cause *folding* and *faulting* of the sedimentary rocks. Folding results from lateral forces of compression.

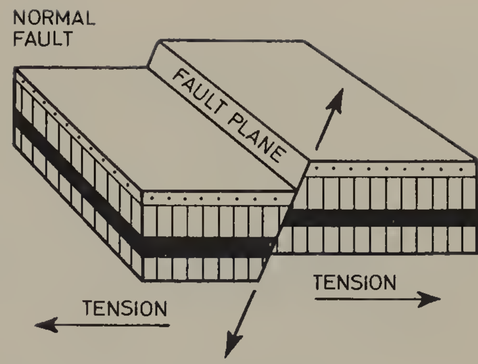


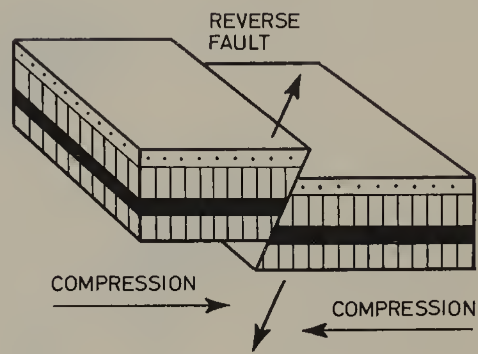




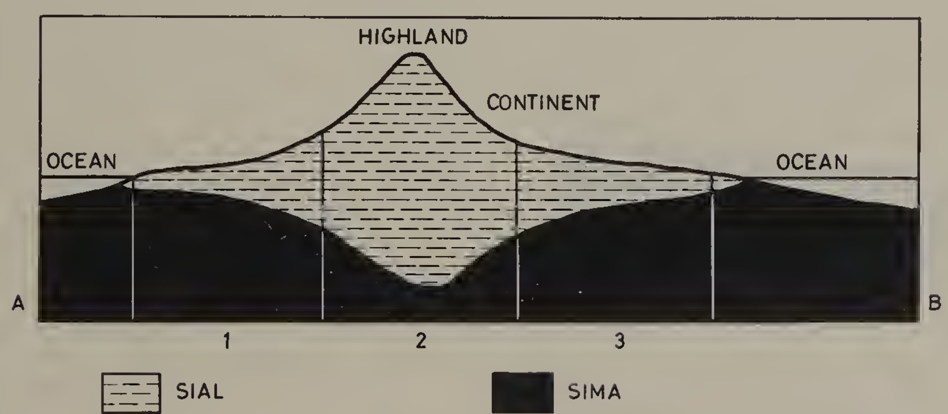
Faulting can be caused by either lateral or vertical forces of either compression or tension. Tension causes a *normal fault* (top right) and compression causes a *reverse fault* (bottom right).





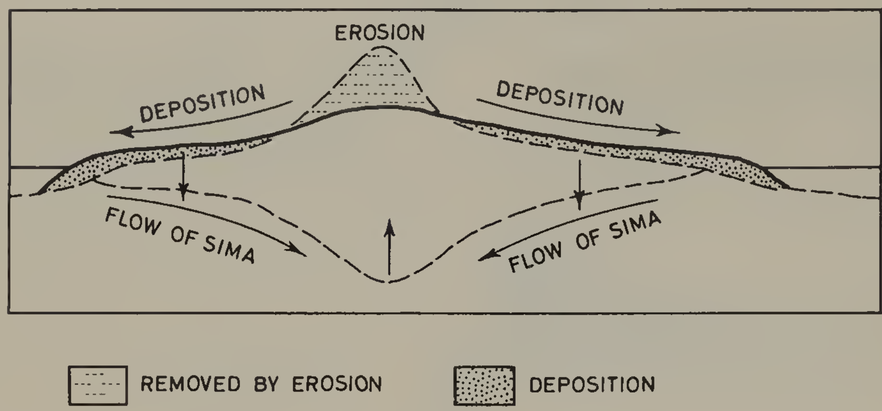


Internal and External Forces Operate Together



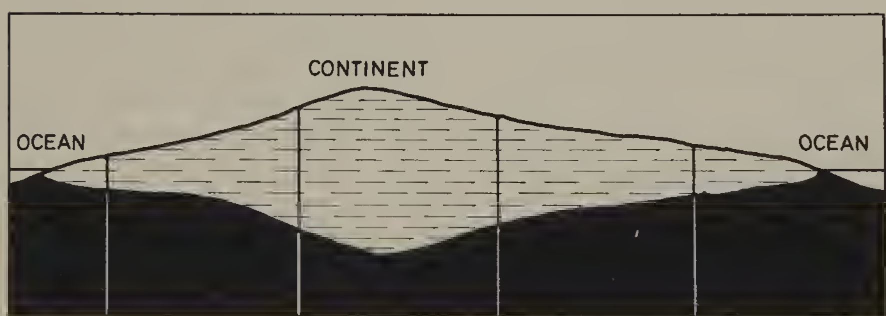
The diagram above contains a section across a continent having a mountain range and the neighbouring oceans. The sial of the continent is regarded as 'floating' on the underlying sima because its density is lower, and because the sima is thought to be in a semi-fluid state. The sial layer is not of uniform thickness and hence the sima layer must also vary in depth in order that a state of balance be maintained between the different parts of the sialic continent. Columns 1, 2 and 3 are of equal area and hence of almost equal weight. The line AB represents the depth at which each column exerts the same pressure and this line coincides approximately with the base of the Earth's crust. At this level the columns are in equal balance with each other.

Erosion and deposition on the continental surface redistribute the weight of the sial on the underlying sima



Any change in the thickness of the sial is accompanied by a change in the thickness of the sima. By this means equal balance is maintained. The highlands are lowered by erosion and the eroded material is deposited on the surrounding lowlands. Sial below the highlands rises and that below the lowlands sinks. Sima 'flows' below the sial from the lowlands to the highlands. This adjustment of balance is reflected on the surface by the bending of the sial block.

Appearance of the section after adjustment of balance has taken place



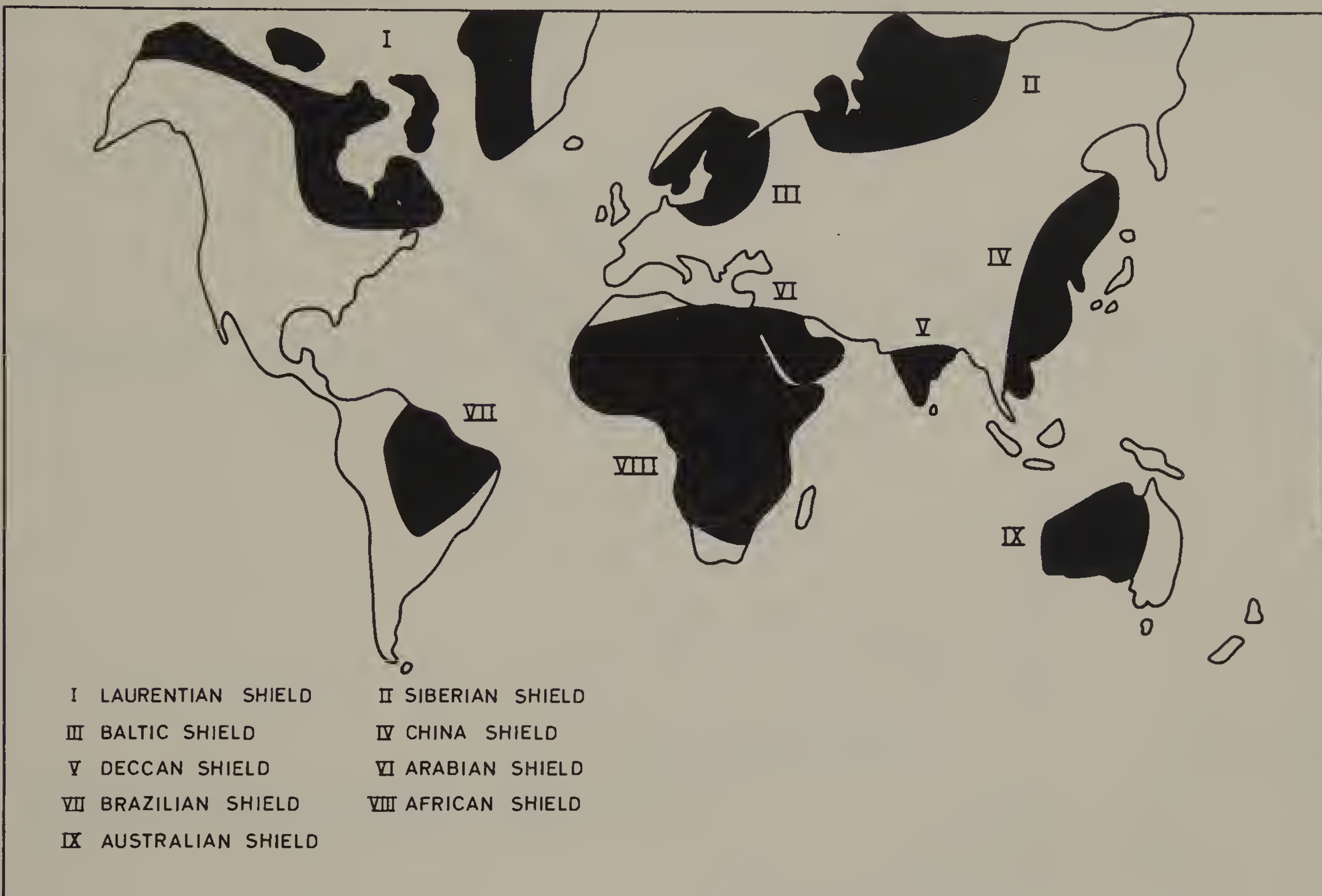
Columns 1, 2 and 3 are still in equal balance. The area of the continent has increased and the thickness of the sial has become more uniform. A zone of sedimentary rocks now surrounds the continent.

Ice Sheets can cause the Earth's Crust to Sag

1 The northern parts of North America and Europe lay under extensive ice sheets of vast thickness during the *Ice Age*. The weight of the ice caused the crust to be depressed.
2 Since the melting of these ice sheets, the crust has been slowly rising. The Scandinavian coasts have many sea beaches which lie from 25′ to 100′ above the present-day sea beaches. Evidence suggests that these *old sea beaches* have been raised because the land has been uplifted.

The Age of Present-day Land Surfaces

The distribution of land surfaces has not always been as it is today. There are large areas of land which are composed of sedimentary rocks which contain shells and the remains of sea organisms. Such rocks must have been laid down in water, and these regions at one time must have formed the floors of seas. There are however many regions composed of very old crystalline rocks which must have been land for long periods of time. These regions are called *stable blocks* or *shields*. The shields are frequently rich in mineral deposits such as *gold*, *silver*, *lead*, *cobalt* and *nickel* and other minerals.



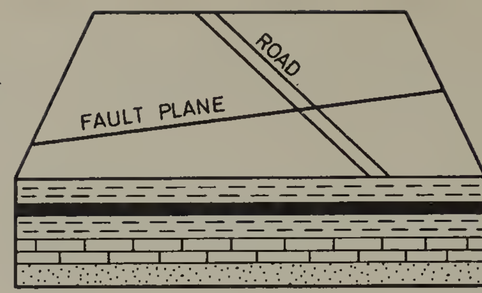
Earth Movements

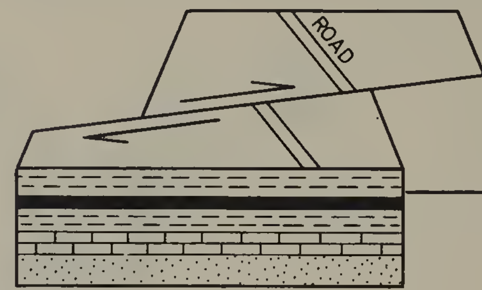
I Earthquakes (sudden earth movements or vibrations in the Earth's crust)
They are caused by:

(i) the development of faults (cracks) in the crust which result from disturbances in the state of balance in the crust by prolonged erosion on land surfaces and prolonged deposition on ocean floors.
(ii) movements of molten rock below, or within the crust.

Nature of Earthquakes

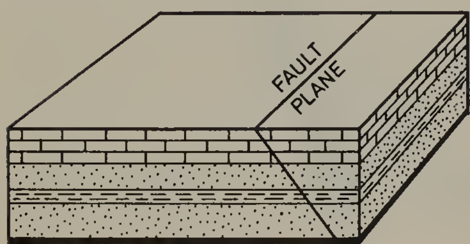
Waves passing out from the point of origin (focus) set up vibrations which may reach up to 200 per minute. The vibrations cause both vertical and lateral movements and this violent shaking causes great destruction to buildings. Earthquakes are frequently associated with faults.

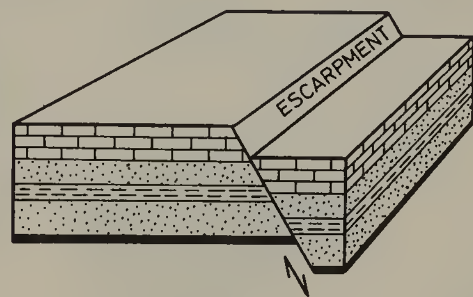




Effects of Earthquakes

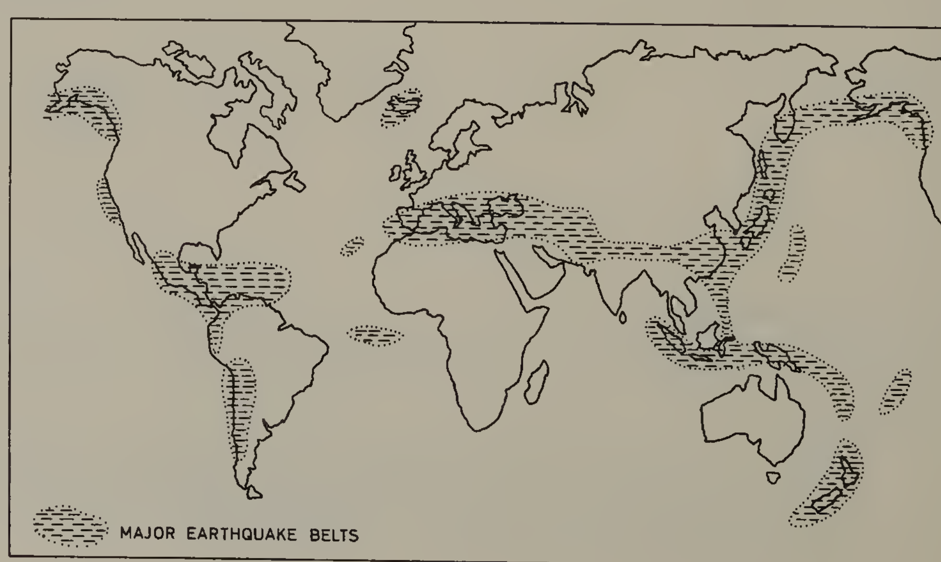
1 They can cause vertical and lateral displacement of parts of the crust.
2 They can cause the raising or lowering of parts of the sea floor as in Sagami Bay (Japan) in 1923. Parts of the Bay were uplifted by 700′, other parts were depressed by 1,000′.
3 They can cause the raising or lowering of coastal regions as in Alaska in 1899 when some coastal rocks were uplifted by 50′.
4 They can cause landslides as in the loess country of North China in 1920 and 1927.





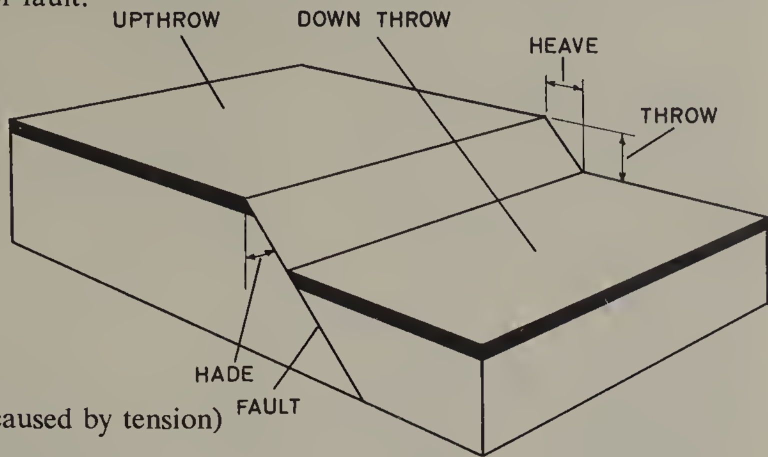
Some Catastrophic Earthquakes

1755	Portugal	Caused depression of the sea floor near Lisbon
1868	Peru	30,000 people killed
1899	Alaska	Coast of Disenchantment Bay uplifted
1906	California	San Francisco destroyed
1906	Chile	3,000 people killed
1920	Japan	Level of Sagami Bay changed and 200,000 people killed
1927	China	Landslides killed 100,000 people
1931	New Zealand	Napier destroyed
1931	Nicaragua	Managua (the capital) destroyed
1962	Iran	Over 20,000 people killed.



II Forces of Tension and Compression

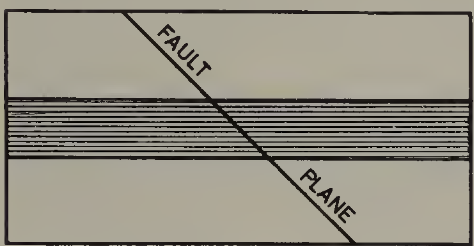
Rocks of the earth's crust are subjected to tension and compression when vertical or lateral earth movements take place. If one part of the crust is compressed then clearly another part must be stretched, i.e. be under tension. Rocks when under tension usually fault, but when under compression they may fold or fault.



Normal Fault (caused by tension)

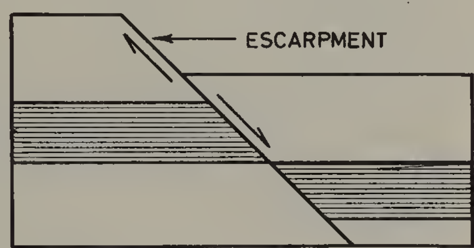
The nature of Faults

Upthrow	upward displacement
Downthrow	downward displacement
Throw	vertical displacement
Heave	lateral displacement
Hade	inclination of the fault to the vertical

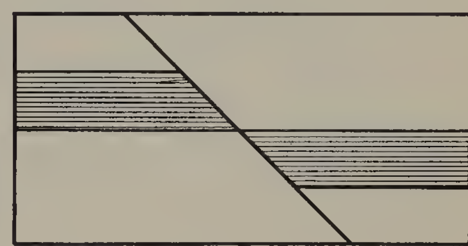


Fault plane develops.

Note Surface area is increased.

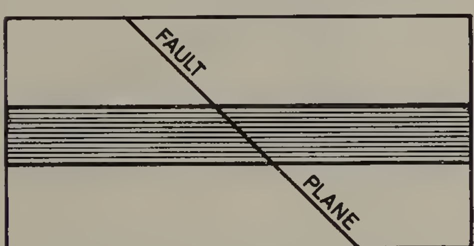


Rocks on each side of the fault plane are usually displaced as shown by the arrows.



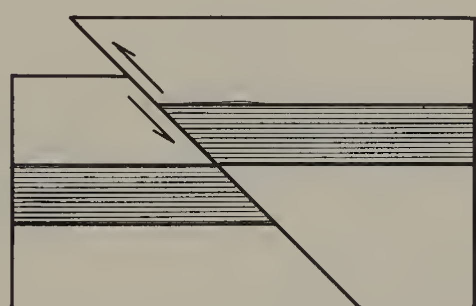
Faulting sometimes produces an escarpment. This is sometimes removed by erosion.

Reverse Fault (caused by compression)

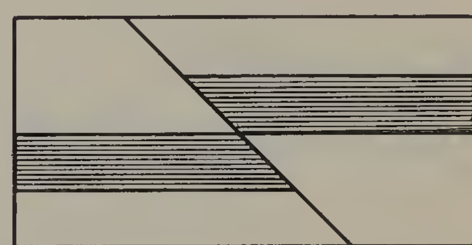


Fault plane develops.

Note Surface area is reduced.

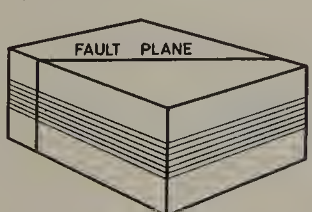


Rocks are displaced as shown by the arrows. Those on one side of the fault plane ride up over those on the other side.

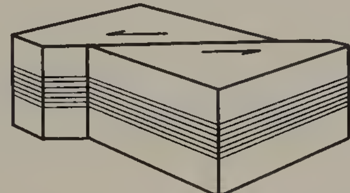


An escarpment may mark the fault. Erosion may later remove this.

Tear Fault



The fault plane is often almost vertical. The rocks are displaced horizontally as shown by the arrows. There is no vertical displacement.



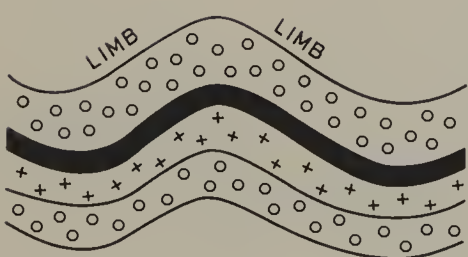
Tear faults usually occur during earthquakes. The earthquakes which wrecked San Francisco produced tear faults.

The Nature of Folds

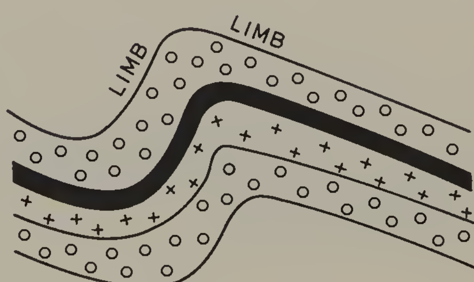
The diagram at the bottom of page 20 shows a *simple fold*. The layers of rock which bend up form an *upfold* or *anticline*. Those which bend down form a *downfold* or *syncline*. The sides of a fold are called the *limbs*.

If compression continues then simple folds are changed first into *asymmetrical folds*, then into *overfolds*, and finally into *overthrust folds*.

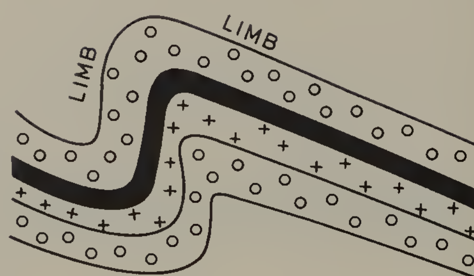
Folded rocks in South-west England



Simple Fold

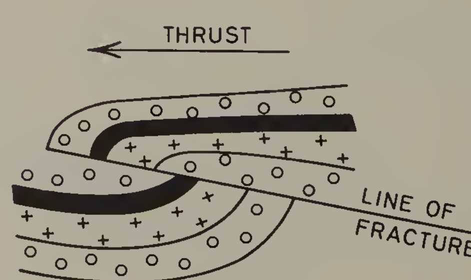


Asymmetrical Fold



Overfold

Asymmetrical fold: one limb steeper than the other
Overfold: one limb is pushed over the other limb
Overthrust fold: when pressure is very great a fracture occurs in the fold and one limb is pushed forward over the other limb.



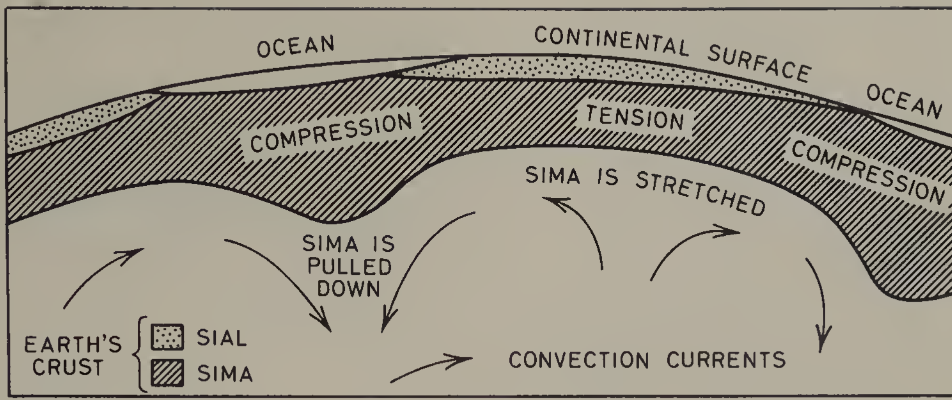
Overthrust Fold

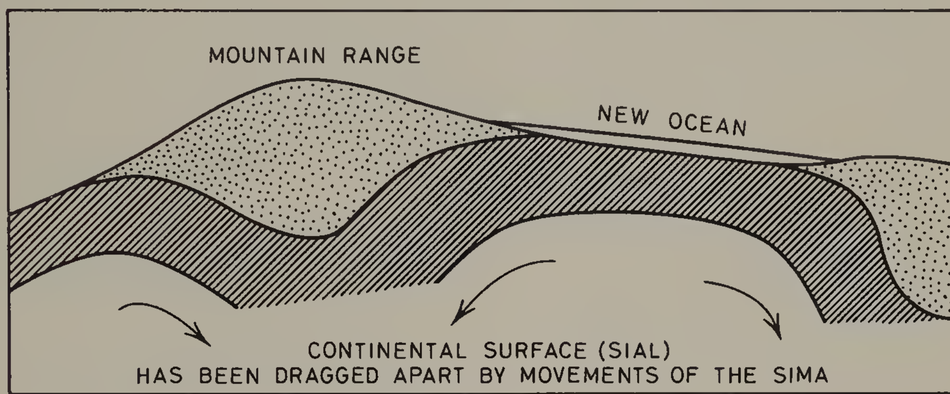
Features Produced by Earth Movements

Fold Mountains

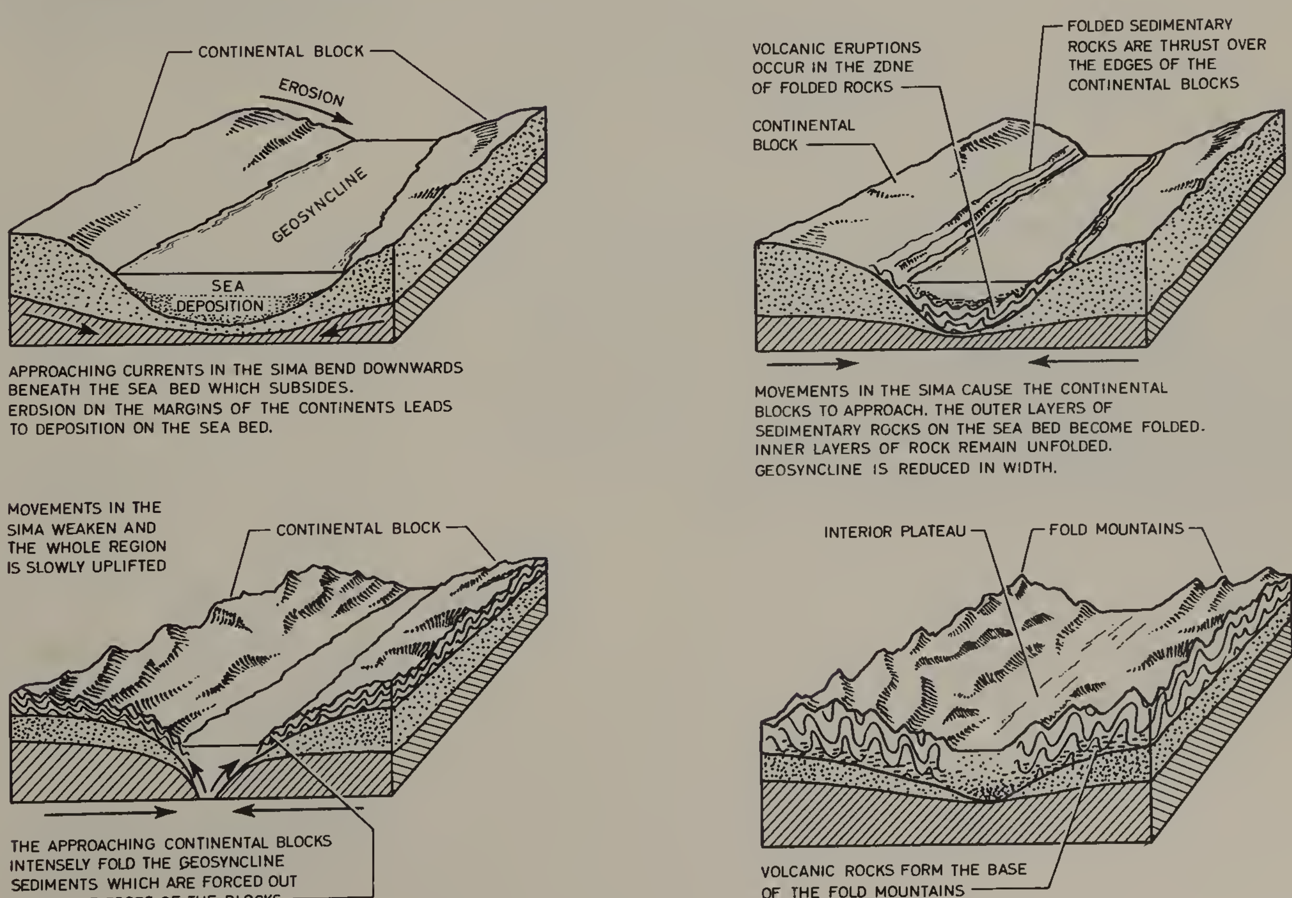
Fold mountains consist of great masses of folded sedimentary rocks whose thickness is often as much as 40,000 or more. The sedimentary rocks in the beginning must have been laid down in horizontal layers which later became folded through compression. The process of folding caused the width of the sedimentary rock zone to decrease and its thickness to increase.

At one time many people believed that fold mountains developed through the contraction of the earth's crust on cooling but this explanation is not accepted today. The origin of fold mountains and other large landforms is much more complex than this. A. Holmes has given an interesting explanation of how these features may have come into being (diagrams on the right) and those who wish to study this in more detail should read Chapter XVIII in *Principles of Physical Geology* by A. Holmes (Ronald).





Possible Origin of Fold Mountains

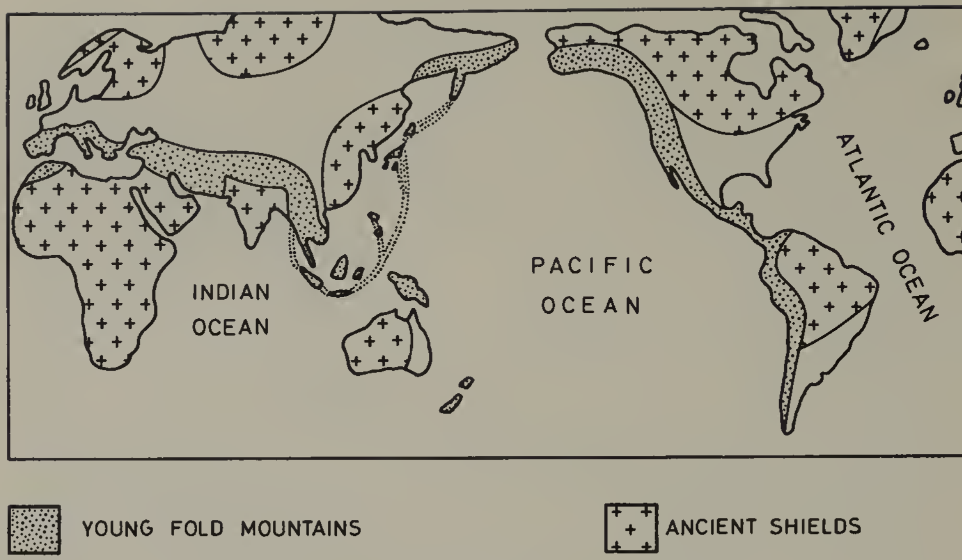


Types of Fold Mountains
Sometimes the folding is never intense and this simple folding gives rise to mountains and valleys. The anticlines become the mountains and the synclines the valleys as in the Jura of France. Simple fold mountains are rare.

Complex folding is much more common. When this happens there is little or no relationship between the anticlines and the mountains, and the synclines and the valleys.

The peaks and valleys which occur in complex fold mountains have been formed by glacial and/or river erosion (this will be dealt with later).

Some complex fold mountains do not appear to have been formed between two continents, e.g. the mountains of Java and Sumatra. The floor of the ocean probably acted as the 'missing' continent.



World Distribution of Young Fold Mountains

The Fate of Fold Mountains

Weathering and erosion attack fold mountains as soon as they begin to form. The building of mountains like the building of all other major features of relief takes vast periods of time to complete. From the beginning of their formation weathering and erosion, operating together, attack and wear away the mountains. To begin with earth movements are more powerful than weathering and erosion and the mountains thus reach heights of thousands of feet, but as earth movements weaken the wearing away process becomes dominant. In time they are reduced to an almost level surface not far above sea level. This surface is called a *peneplain.*

How many times have Fold Mountains formed on the earth's surface?
There is evidence to show that there have been three main mountain building periods. The remnants of the first of these can be seen in the Altai Mountains, the Scandinavian Mountains and the Lake District of England. Remnants of the second mountain building period occur in the Tien Shan Mountains and in the plateaus of Central France and Spain. As far as present-day mountain systems go it is the last mountain building period which is the most important. Mountains belonging to this period include the Himalayas, Andes, Rockies and Atlas Mountains. They are all called *Young Fold Mountains* (see diagram at top of page).

Is Mountain building still going on?

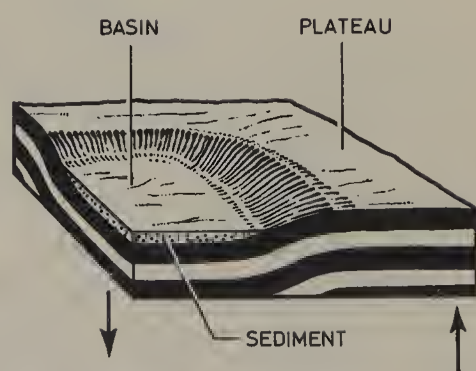
We know that as fold mountains are worn away the deposition of sediments in neighbouring oceans gives rise to new sedimentary rocks. Scientific surveys show that there is an extensive geosyncline forming from south of the Atlas Mountains to south of Indonesia. The geosyncline is represented by the Shotts of Tunisia and Algeria, the Mesopotamian Alluvial Plain, the Persian Gulf, the Indo-Gangetic Plain and the ocean deep south of Java. The stage of mountain building reached in the geosyncline varies from one part of it to another. In the eastern part there is frequent volcanic activity.

Influence of Fold Mountains on Human Activities

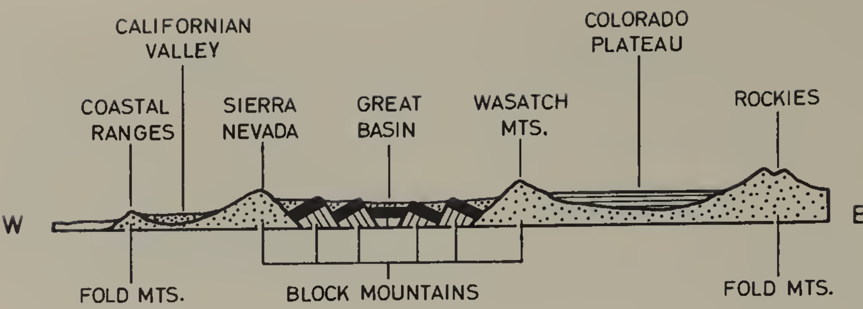
1 They often act as climatic barriers. Regions on one side of a mountain range may have an entirely different climate from that of the region on the other side. The coastlands of British Columbia have mild winters, warm summers and rain throughout the year. To the east of the Rockies the Prairies have cold winters, hot summers and there is a maximum of rain in the summer.
2 They often receive heavy rain and/or snow which may give rise to important rivers. Most of the rivers of Asia rise in the mountain ramparts of Central Asia. These rivers may be used for irrigation, e.g. the Ganges and Indus, or they may be used for developing hydro-electric power (H.E.P.), e.g. the Colorado and Columbia and the rivers of Switzerland and Japan, or they may be used for both irrigation and developing H.E.P., e.g. Murray River in S.E. Australia.
3 Some mountains and their plateaus may contain minerals, e.g. Nevada (copper and gold), Bolivia (tin).
4 They may act as barriers to communications or they make the construction of communications difficult.
5 Some mountain ranges have valuable timber resources, e.g. Coast Ranges of Western America (coniferous soft woods), Foothills of the Himalayas (teak).

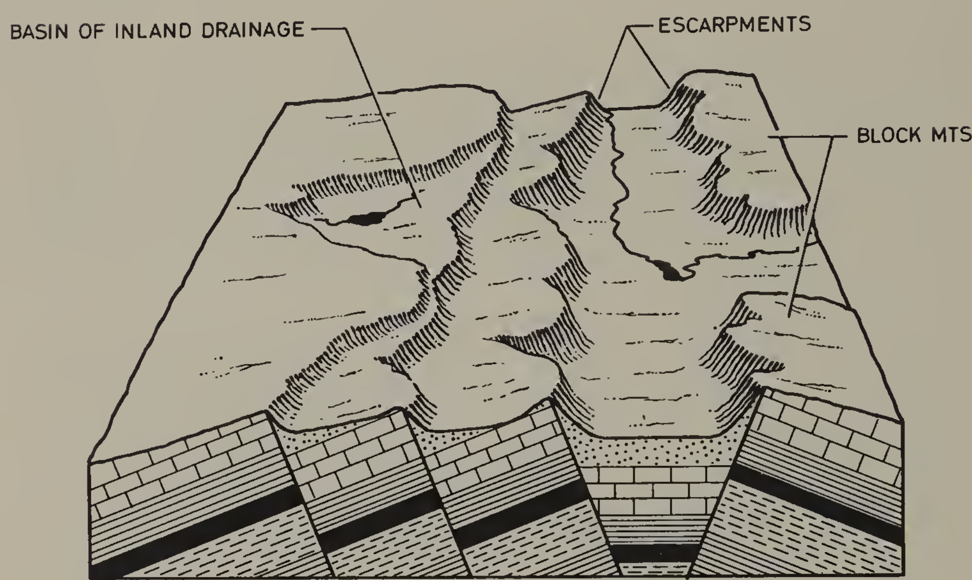
Basins and Plateaus

Vertical earth movements can cause the crust to warp, and sometimes large sections of it are uplifted whilst others are depressed. The uplifted sections form *plateaus* and the depressed sections *basins*. The plateaus of East Africa, Tibet and Colorado have been formed in this way. Basins are of several types. Some are sea-basins, e.g. the Celebes Sea (Indonesia) and the Black Sea (U.S.S.R.); others are high above sea level and rimmed by mountains, e.g. Lake Victoria Basin (East Africa), the Great Basin of Nevada (U.S.A.) and the Tarim Basin (Central Asia); and others are filled with sediments and either have an external drainage, as in the Congo Basin (Central Africa), or are basins of inland drainage, as in the Chad Basin (North Central Africa) and the Tarim Basin (Central Asia).



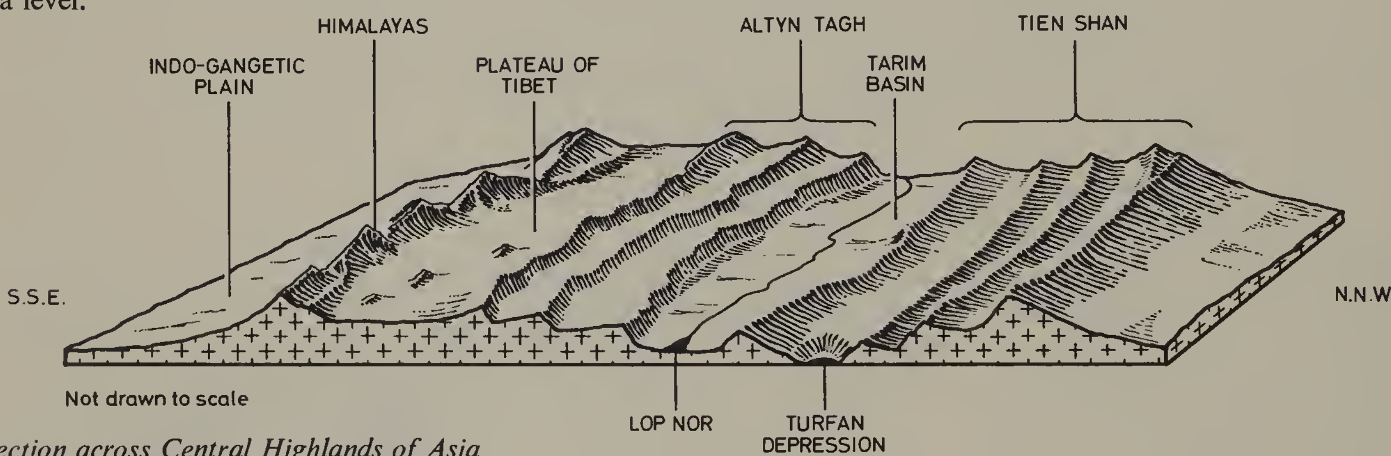
At the top of the page is a diagrammatic section across the Western Highlands of the U.S.A. The Colorado Plateau is an intermontane plateau and lies between the Rockies and the Wasatch Mountains. The Great Basin is really a plateau which has been block-faulted (see second diagram). Block sections of the Plateau now form block mountains. Some of the depressions of the Great Basin have no external drainage and because of a high rate of evaporation salt lakes frequently form. Some of these dry up and form salt flats or *playas*.





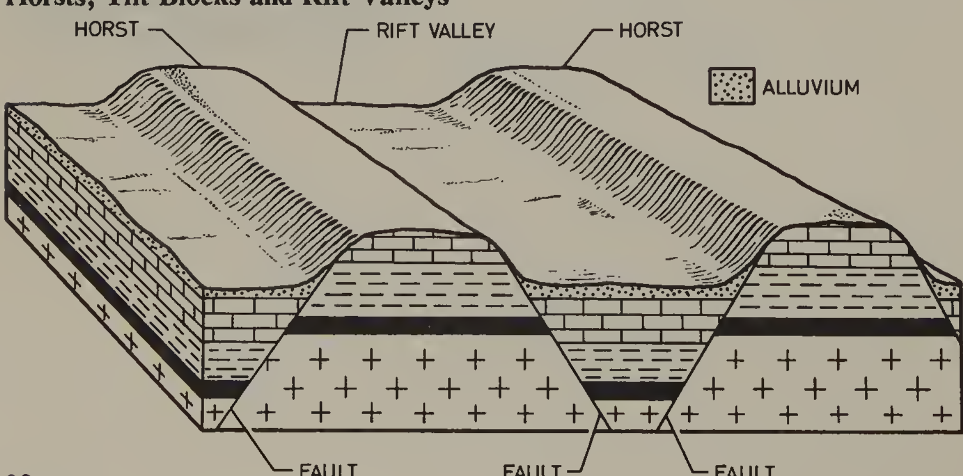
Block Faulting in the Great Basin (U.S.A.)

Central Asia contains numerous plateaus and basins. Tibet is the highest plateau in the world and is an intermontane plateau. The Turfan Depression lies below sea level while the Tarim Basin is between 2,000 and 6,000 feet above sea level.



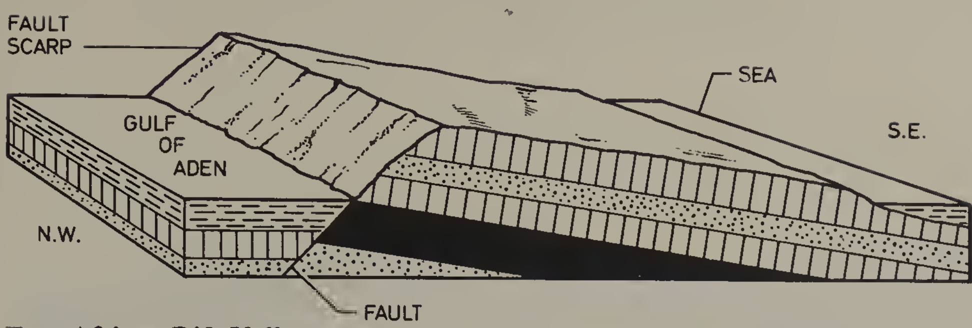
Section across Central Highlands of Asia

Horsts, Tilt Blocks and Rift Valleys



Earth movements sometimes cause the crust to be divided into rectangular-shaped blocks some of which are uplifted and others are depressed. This is called *block-faulting*. Uplifted blocks may either be tilted when they form *tilt blocks* or they may be horizontal to form *horsts*. The tilt block usually has one pronounced scarp, e.g. the Western Ghats of the Deccan, while horsts have two pronounced scarps.

TILT-BLOCK MOUNTAIN OF SOMALIA (E. AFRICA)



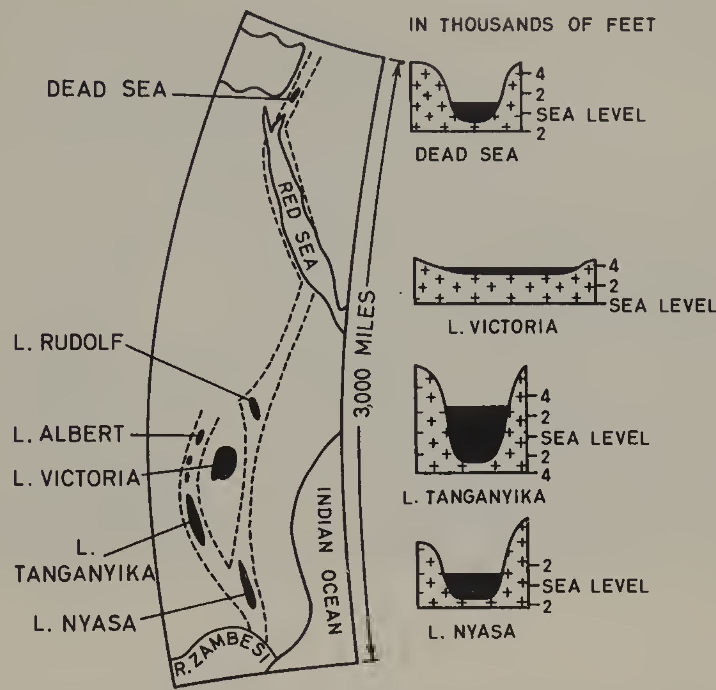
Tilt Blocks	*Horsts*
Deccan Plateau	Korea
Arabian Plateau	Sinai
Brazilian Plateau	Black Forest

When blocks of the crust are depressed between parallel faults they often form *rift valleys.*

East African Rift Valleys

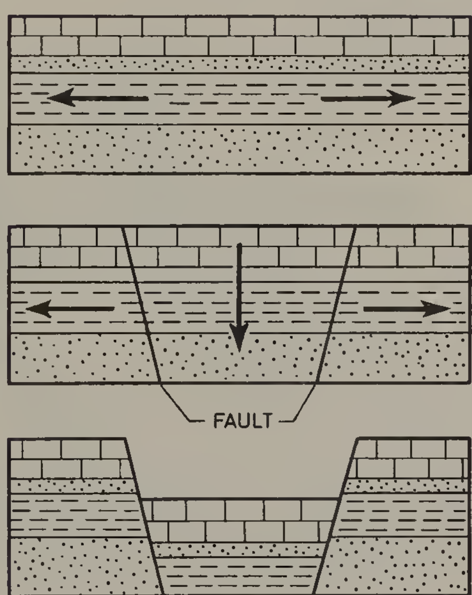
The most outstanding belt of rift valleys extends for 3,000 miles from Syria to the River Zambesi in East Africa. The belt contains a number of well-developed rift valleys some of which contain lakes whose beds are below sea level. Many of the valleys have precipitous sides which are fault scarps and which are often very straight for many miles. The broken line on the map indicates the main belt of rift valleys.

The River Rhine in Europe flows through an impressive rift valley between the fault blocks of the Black Forest and the Vosges.



Origin of Rift Valleys

They are thought to have developed either from the action of tensional forces in the crust which caused fault blocks to sink between parallel faults, or from the action of compressional forces in the crust which caused fault blocks to rise up towards each other and over a central block. Many people think that compression has been responsible for most rift valleys. They argue that it would not be possible for blocks of the crust to sink into the heavier rocks of the sima below the crust.

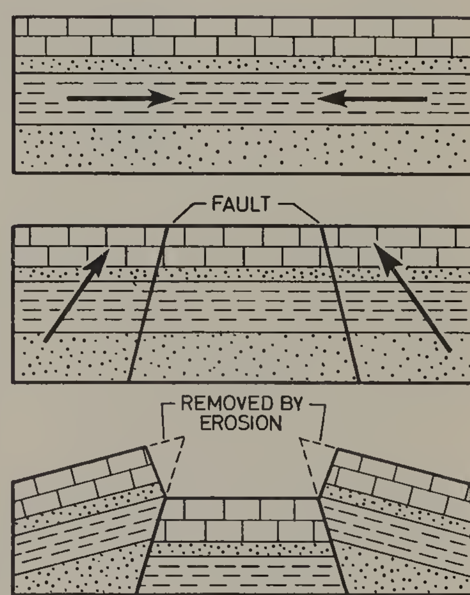


Formed by Tension

Layers of rocks are subject to tension.

Faults develop and the centre block begins to subside.

After subsidence a depression with steep fault scarp sides, i.e. a rift valley, is formed.



Formed by Compression

Layers of rocks are subject to compression.

Faults develop and the outer blocks begin to thrust up over the centre block.

The overhanging sides of the rift valley are worn back by erosion.

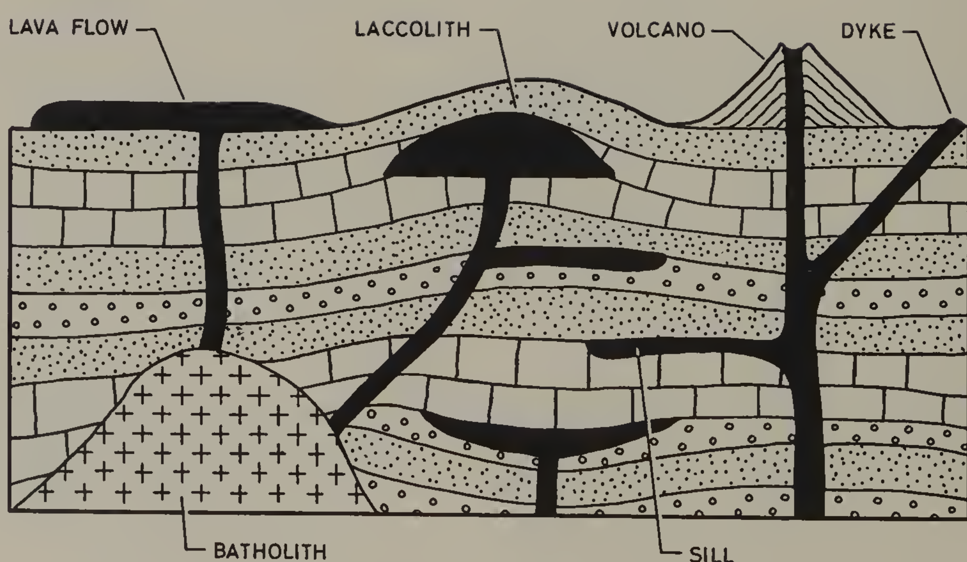
Influence of Plateaus on Human Activities

1 Some plateaus are rich in mineral deposits, e.g. the Highlands of Brazil (iron ore and manganese); the African Plateaus (copper and gold); Western Australia (gold).
2 High plateaus in tropical latitudes are sometimes of agricultural value, e.g. the Kenya Plateau (coffee, sisal and maize); the Brazilian Plateau (coffee).

Jordan Rift Valley

Volcanic Action and the Features it Produces

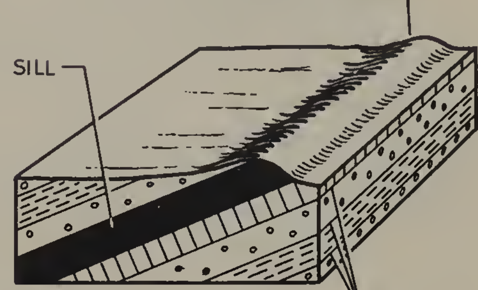
Rocks below the crust have a very high temperature, but the great pressure upon these keeps them in a semi-solid state. If the pressure weakens (as happens when faulting or folding takes place) then some of the rocks become liquid. This liquid is called *magma*. The magma forces its way into cracks of the crust and may either reach the surface where it forms *volcanoes* or *lava flows*, or it may collect in the crust where it forms *batholiths*, *sills* and *dykes*. Magma reaching the surface may do so quietly or with great violence. Whichever happens it eventually cools and solidifies.
This diagram shows the chief types of volcanic forms. They do not occur together like this.



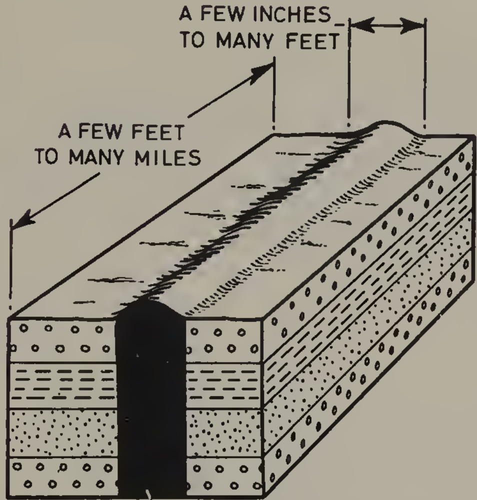
Volcanic Features formed in the Crust

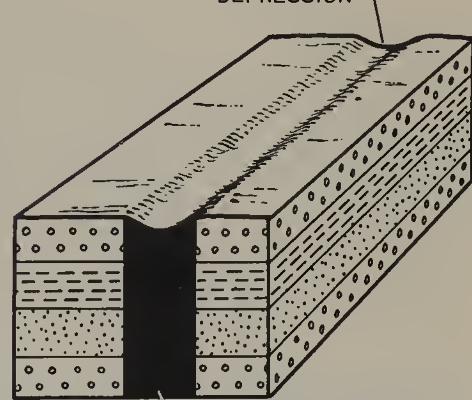
Batholith This is a very large mass of magma which often forms the roots of a mountain. It is made of granite and can become exposed on the surface by the removal of the overlying rocks by erosion.

Sill When a sheet of magma lies along the bedding plane it is called a sill. Some sills form ridge-like escarpments when exposed by erosion, e.g. Great Whin Sill in Northern England. Others may give rise to waterfalls and rapids where they are crossed by rivers.



Dyke When a mass of magma cuts across the bedding planes and forms a wall-like feature it is called a dyke. Dykes may be vertical or inclined. Some dykes when exposed on the surface resist erosion and stand up as ridges or escarpments. Others are easily eroded and form shallow depressions. Examine the two diagrams on the right. Like sills they sometimes give rise to waterfalls or rapids.

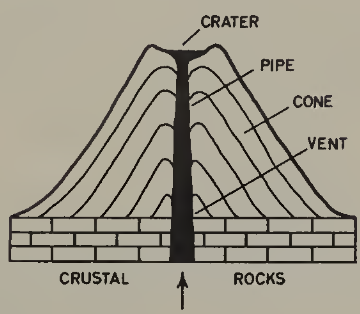




Volcanic Features formed on the Surface

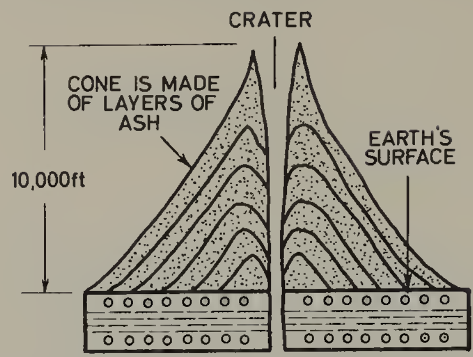
Sometimes magma reaches the surface through a *vent* (hole) or a *fissure* (crack) in the surface rocks. When magma emerges on the surface it is called lava. If lava emerges via a vent it builds up a volcano (cone-shaped mound) and if it emerges via a fissure it builds up a *lava platform*.

Structure of a Volcano



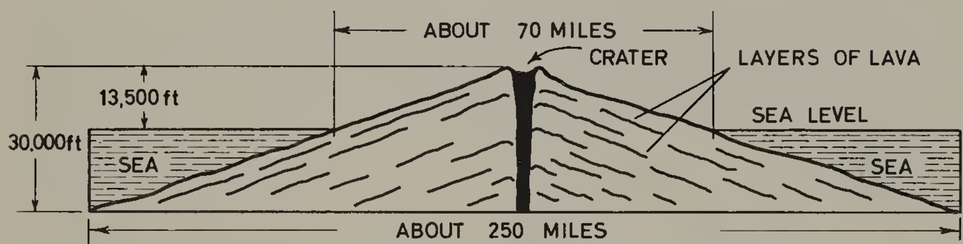
The Cone is made of either lava, or a mixture of lava and rocks torn from the crust, or ash and cinders (small fragments of lava).

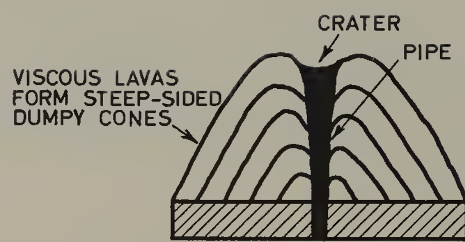
1 *Ash and Cinder Cone*



When lava is violently ejected it is blown to great heights and it breaks into small fragments. These fall back to earth and build up a cone. Examples: Vulcano de Fuego (Guatemala), Paracutin (Mexico).

2 *Lava Cones* The slope of the cones depends upon whether the lava was fluid or viscous when it was molten.

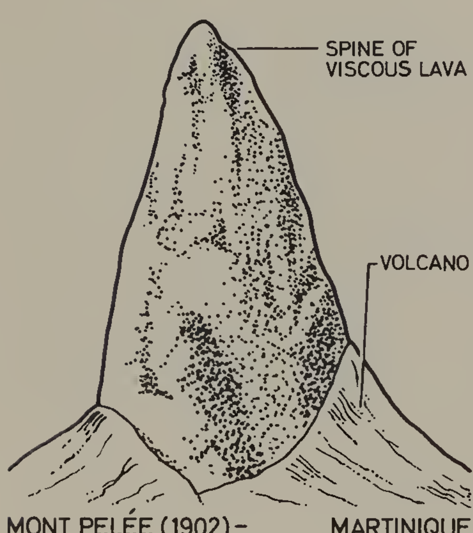


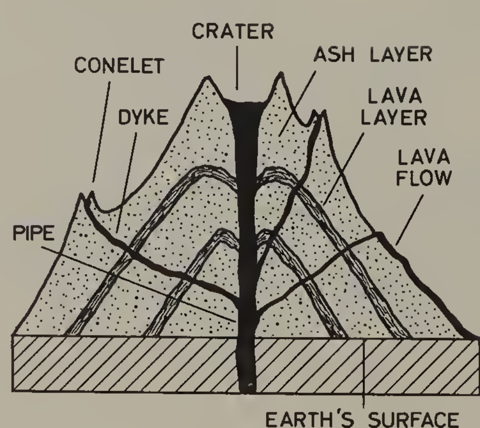


Fluid lavas give rise to gently sloping cones, e.g. Mauna Loa (Hawaii).

Viscous lavas give rise to steeply sloping cones. Sometimes the lavas are so viscous that when they are forced out of the volcano they form a *spine* or *plug*.

3 *Composite Cone* This is made of alternate layers of lava and ash.

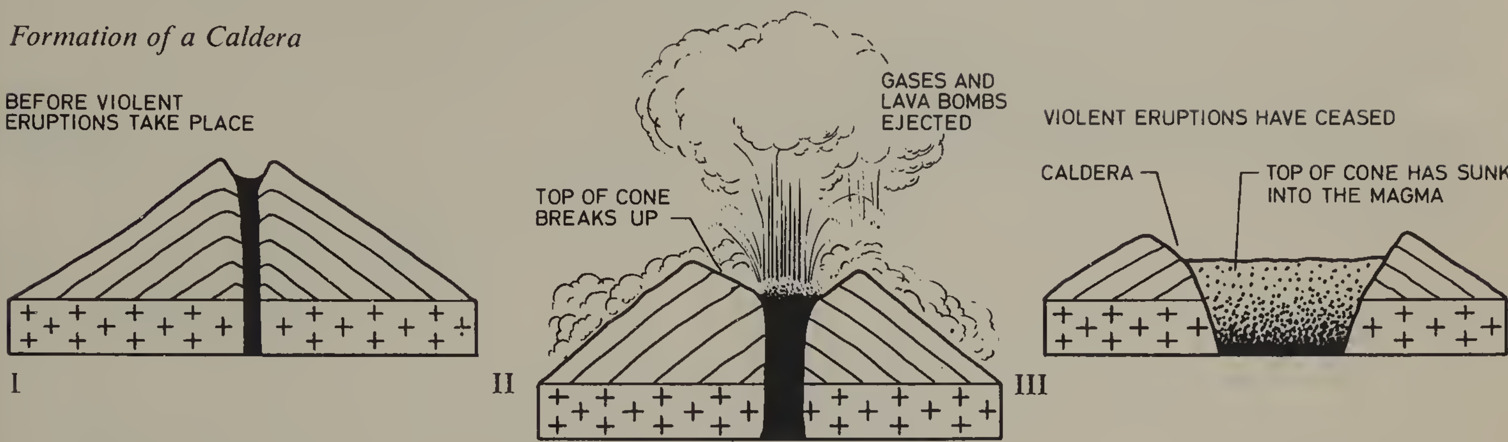




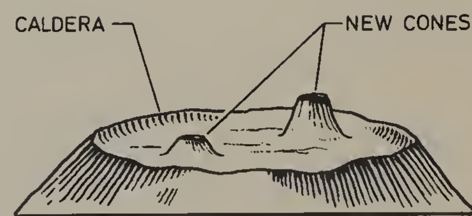
Spines are rare because they often rapidly break up on cooling. This was the fate of Mont Pelée.

This type of volcano begins each eruption with great violence which accounts for the layers of ash. As the eruption gets under way the violence ceases and the lava pours out forming layers on top of the ash. Lava often escapes from the sides of the cone where it builds up small conelets. The best examples of this type of volcano are *Vesuvius* (Italy), *Etna* (Sicily) and *Stromboli* (Italy). Sometimes explosive eruptions are so violent that the whole top of the volcano sinks into the magma beneath the vent. A huge crater called a *caldera* later marks the site of the volcano.

Formation of a Caldera



A caldera may become the site of a lake, e.g. *Lake Toba* (Northern Sumatra) and *Crater Lake* (U.S.A.). Sometimes eruptions begin again and new cones form in the caldera, e.g. *Krakatoa* (Sunda Strait). The town of Crater near Aden is built in a caldera.



Caldera with new cones

Volcanic Activity

Are Volcanoes always Active?

Volcanoes usually pass through three stages in their life cycle. In the beginning eruptions are frequent and the volcano is *active*. Later eruptions become so infrequent that the volcano is said to be *dormant* (sleeping). This is followed by a long period of inactivity. Volcanoes which have not erupted in historic times are said to be *extinct*.

Like all land forms a volcano is attacked by weathering and erosion and by the time it is extinct most if not all the volcano may have been removed. Sometimes the neck of lava remains and this stands up as a steep-sided *plug*. There are many plugs in Central France and some of them became the sites of castles in the Middle Ages (see photograph on the right).

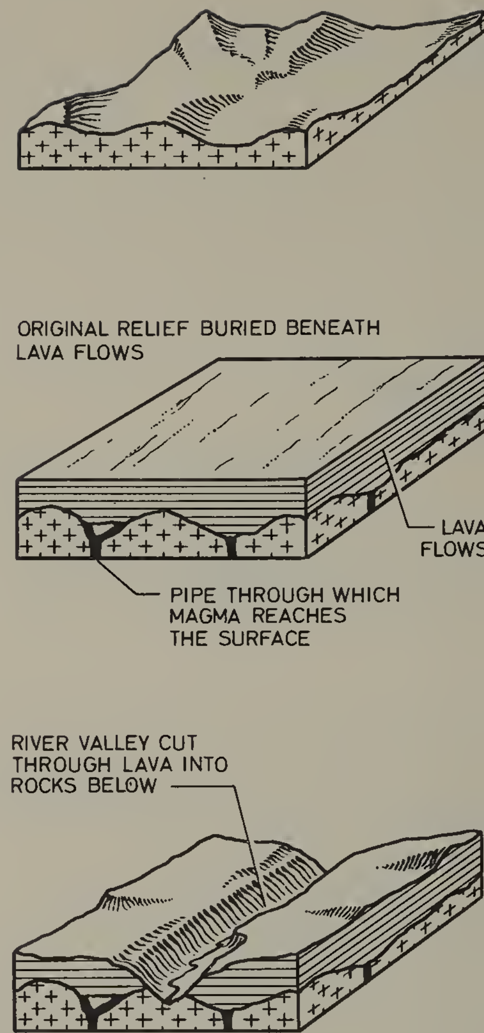
Le Puy in Central France

Fissure Eruptions and the Features they form

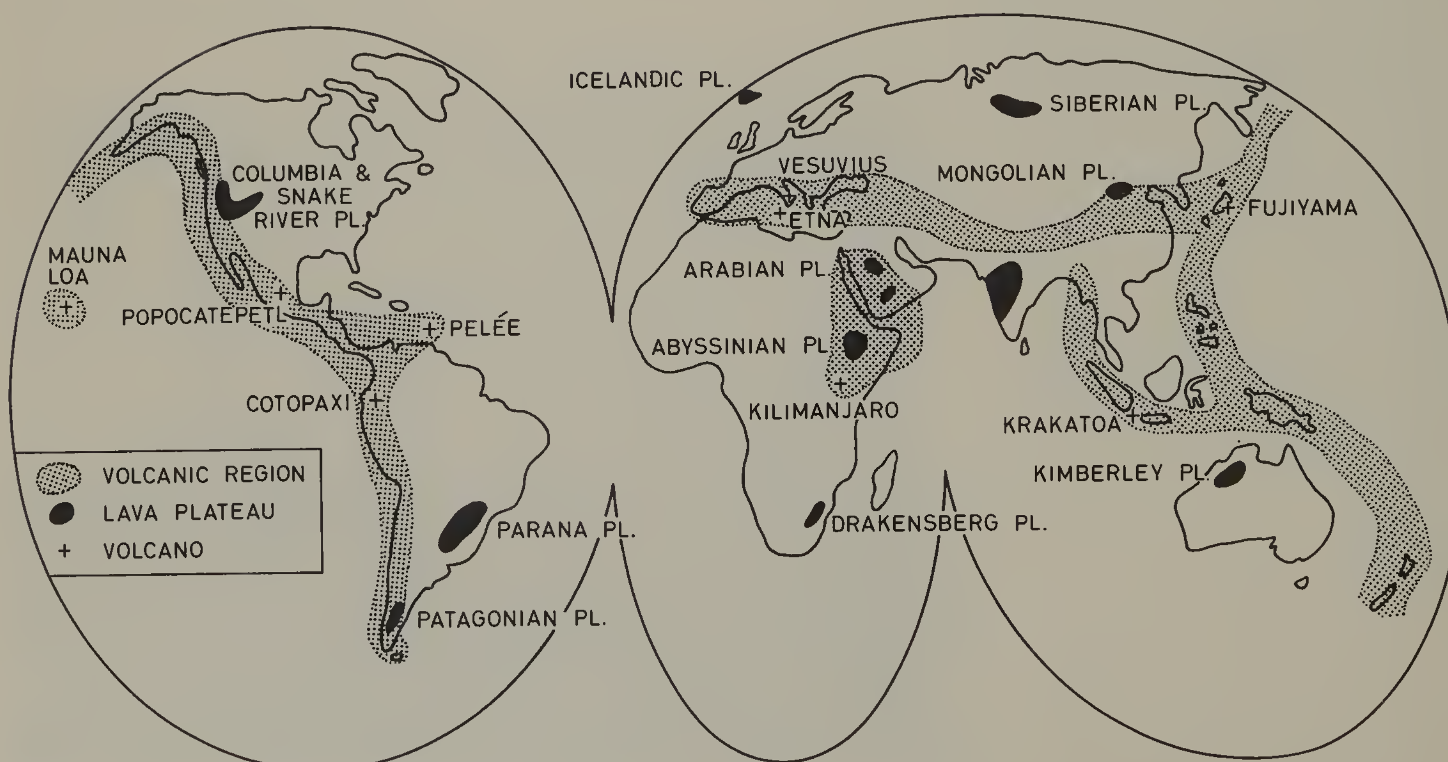
Large quantities of lava quietly well up from fissures and spread out over the surrounding countryside. Successive lava flows result in the growth of a lava platform which may be extensive and high enough to call a plateau. The thickness of such lava plateaus may be as much as 6,000 feet (Deccan lava plateau near Bombay).

Examples of lava plateaus are: Columbia and Snake Plateau of North America (200,000 sq. mls.); North West Deccan of India (250,000 sq. mls.); parts of South Africa where the edge of the plateau forms the Drakensberg Mountains; Victoria and Kimberley Districts of Australia.

Rivers crossing lava plateaus often carve out deep gorges, e.g. Snake River of Oregon (North America). Sometimes the lavas weather to give fertile soils, as in the North West Deccan which is used for cotton cultivation.



Stages in the formation of a lava plateau



World Distribution of Volcanoes and Lava Plateaus

Why do some Volcanoes Erupt Violently?
Most magma contain gases which are under great pressure. In some instances there is a sudden decrease in pressure in the rising magma which causes the gases in it to expand very rapidly. This sudden expansion can cause violent explosions. Water vapour is often one of the gases and it may have originated from the magma or from water in the crust with which the magma came into contact. Many of the gases burn with a fierce heat and some of them like sulphur gases can form a dense cloud which rolls down the side of the volcano killing everything in its path. When eruptions are violent the lava explodes into small pieces which are blown to great heights. The sizes of the pieces vary from grains to small chunks of rock. The latter are called volcanic bombs. If the explosions are particularly violent the fine dust can reach such great heights that it gets carried along by the air currents of the upper atmosphere. When Krakatoa exploded in 1883 some of its dust passed right round the world causing vivid sunsets in many countries.

Other forms of Volcanic Activity
Emissions of gases and steam periodically take place from dormant volcanoes. Similar emissions of gases and steam take place in some volcanic regions where active lava eruptions have long since ceased. Superheated water may flow quietly as in *hot springs*, or it may be thrown out with great force and accompanied by steam as in *geysers*. Thus a geyser differs from a hot spring in that its water is ejected explosively. Geysers often form *natural fountains*. Hot springs and geysers are common in *Iceland*, *North Island* of *New Zealand* and the *Yellowstone National Park* of *U.S.A.*

Influence of Volcanic Eruptions on Man

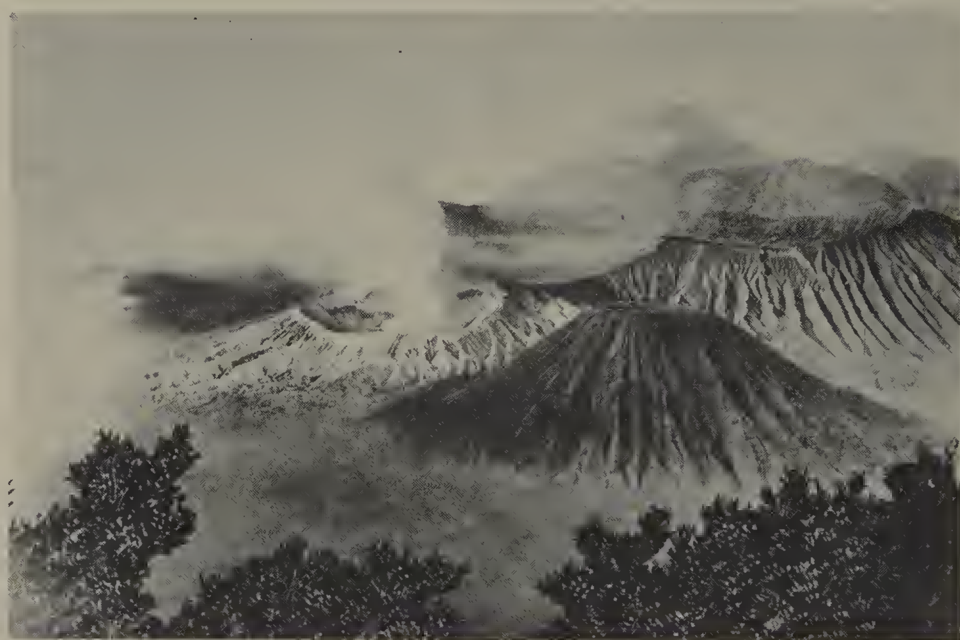
Destructive Influences

1 Some eruptions cause great loss of life, e.g. *Vesuvius* in A.D. 79 (out-pourings of gases and ash); *Krakatoa* in 1883 (caused great sea waves which drowned 40,000 people in neighbouring islands); *Mont Pelée* in 1902 (out-pourings of gases killed 30,000 people).
2 Some eruptions cause great damage to property, e.g. Vesuvius buried Herculaneum and Pompeii with ash; Mont Pelée caused the destruction of St. Pierre.

Constructive Influences

1 Some lava out-pourings have weathered to give fertile soils, e.g. in Java, the north-western part of the Deccan Plateau, and the plains around Etna. These regions are of important agricultural value.
2 Volcanic activity sometimes results in the formation of *precious stones* and *minerals*. These occur in some igneous and metamorphic rocks, e.g. *diamonds* of *Kimberley*; *copper deposits* of *Butte* (U.S.A.); and the *nickel deposits* of *Sudbury* in Canada.
3 Some hot springs are utilised for heating and supplying hot water to buildings in New Zealand and Iceland.

Bromo and Batok in Java



These cones are made of ash and cinders. The sides are deeply grooved by rain erosion. The flat land around the volcanoes consists of fine black volcanic dust.

Mt. Meru in Tanganyika

The caldera of this volcano contains a conelet, the vent of which is clearly visible. Note the steep walls of the caldera.

Volcano Cerro de Lopizio in Mexico

In this aerial view the cone and its crater stand out extremely well. This volcano is only 30 miles south of Paracutin which first erupted in 1943 and which is now 1,500 feet high.

Chapter 3 External Forces

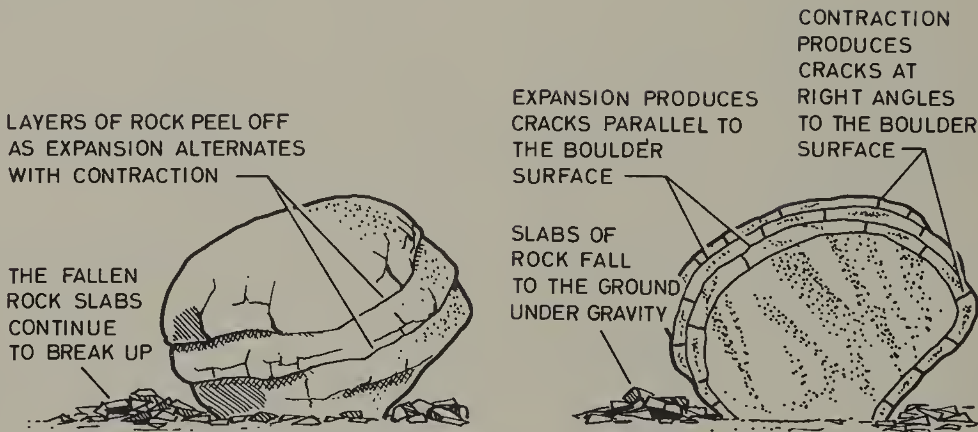
External forces lower the level of the land by wearing it away and this process is called denudation. They also raise the level of the land by deposition. Denudation consists of (i) Weathering, (ii) Erosion.
Weathering refers to the gradual disintegration of rocks which lie exposed to the weather. The effect of weathering can be seen on stone monuments and buildings where pieces of stone have flaked off, and on iron railings which have rusted.
Erosion refers to the disintegration of rocks which lie exposed to what are called the agents of erosion, i.e. running water, wind and moving ice.
Deposition refers to the laying down of rock particles by the agents of erosion.

Weathering

It is effected by physical forces and chemical forces.

Physical Weathering

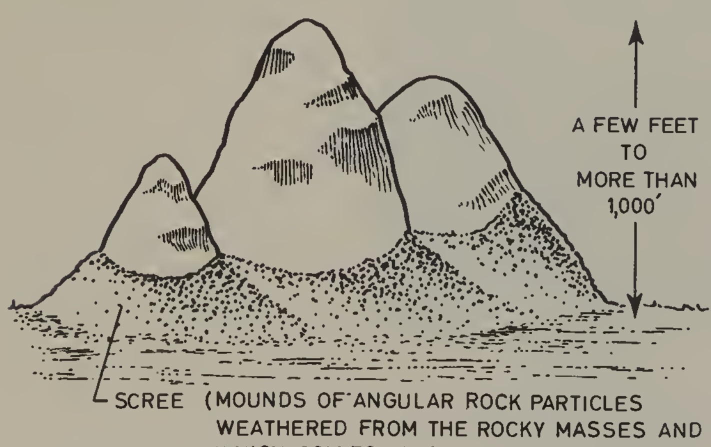
I *By Temperature Changes*
In arid regions, such as hot deserts, rock surfaces heat up rapidly when exposed to the sun and the surface layers expand and break away. At night when the temperature falls rapidly the same layers contract and more cracks develop. In time the layers of rock peel off and fall to the ground. Rock break-up of this type is called *exfoliation*. Exfoliation is best seen in rocks of uniform structure. This process ultimately changes rocky masses into rounded boulders.



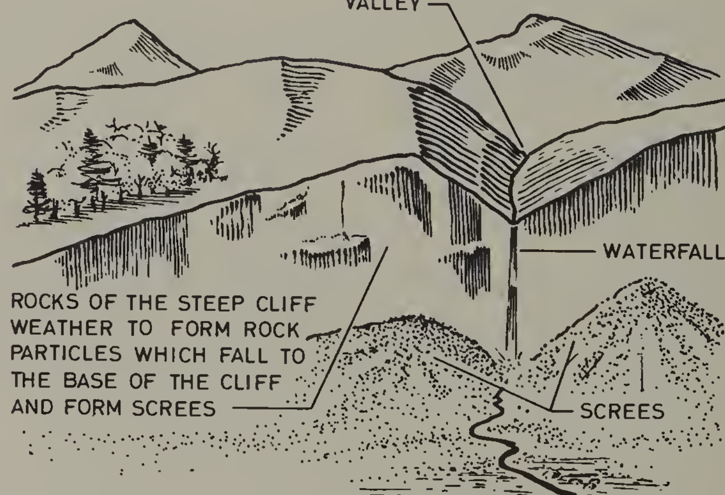
LARGE BOULDER SHOWING BREAK-UP BY EXFOLIATION

SECTIONAL VIEW OF THE SAME BOULDER

EXFOLIATION DOMES



Exfoliation domes are common in the Kalahari, Egyptian and Sinai Deserts.



Physical weathering on steep slopes often produces *screes* which collect at the bottom of the slopes.

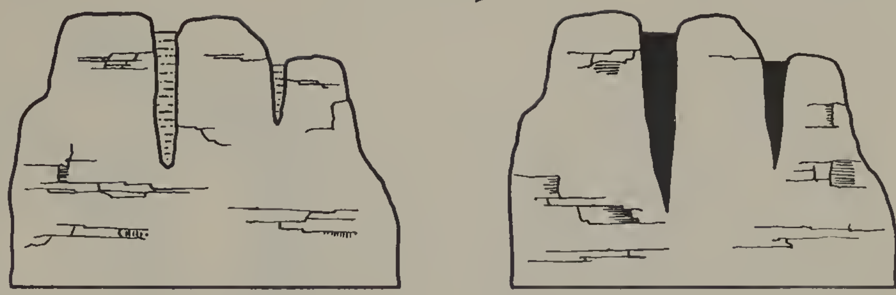
II *By Frost Action*

When water freezes its volume increases. If water in the cracks of rocks freezes a tremendous power is applied to the sides of the cracks and the cracks widen and deepen.

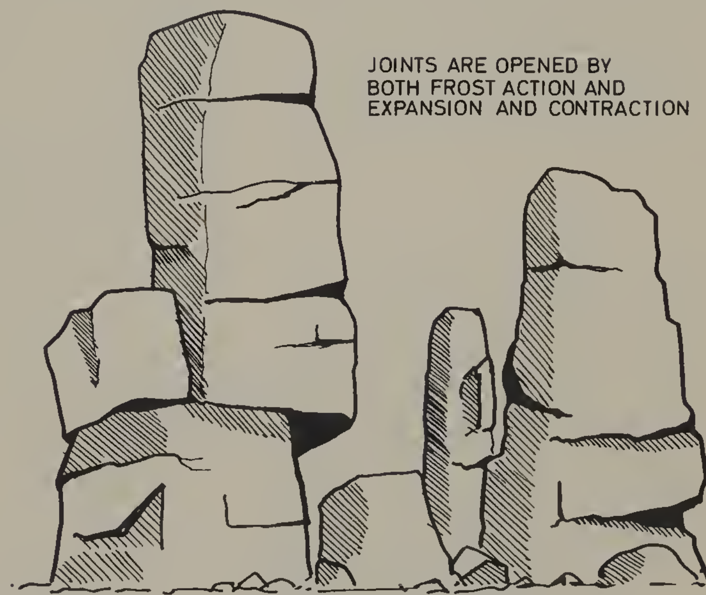
Frost action in time breaks up rocky outcrops into angular blocks which later break up into small fragments.

Frost action is very common in the winter season in temperate regions and in some high mountains all the year, e.g. the Himalayas. It usually involves the freezing of water in the cracks of rocks during the night and the thawing of the ice during the following day. The angular fragments of rocks which break off the main rocky masses through frost action form *screes* around the lower slopes of the rocky outcrops.

Note Screes formed by frost action contain *angular rock particles*, those formed by other types of weathering contain *rounded rock particles*.



Some rocks break up into large rectangular-shaped blocks under the action of mechanical weathering. This may be partly frost action and partly expansion and contraction through temperature changes. This is called *block disintegration*.

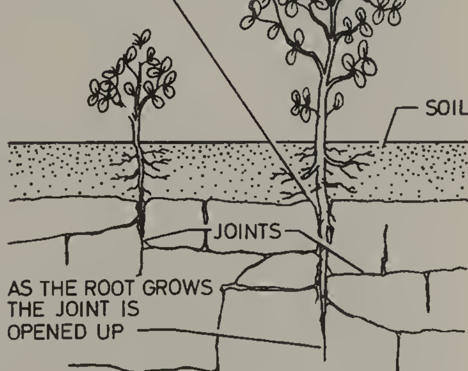


BLOCK DISINTEGRATION

III *By Plant and Animal Action*

The roots of plants, especially trees, can force joints and cracks apart in rocks. Some animals by burrowing also help to break up rocks.

Note A covering of vegetation often protects rocks from weathering. It binds the soil together and reduces changes in temperature. The removal of a covering of vegetation can result in rapid weathering or *soil erosion*.

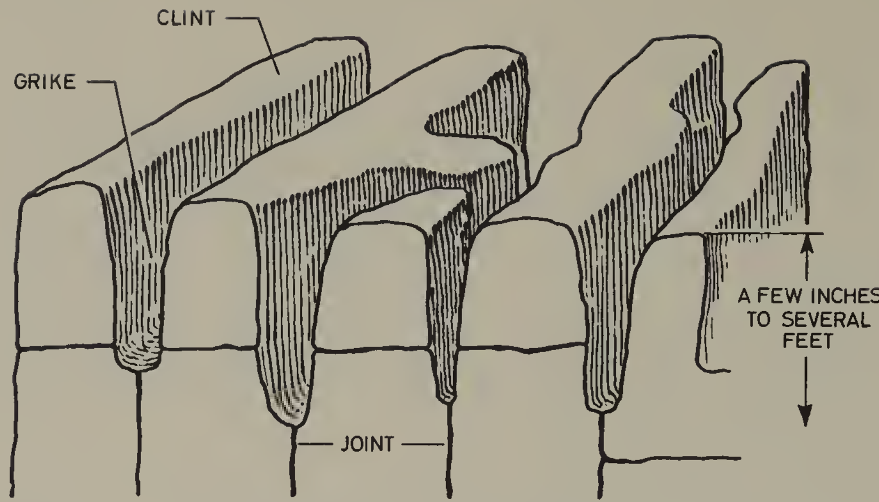


Chemical Weathering

I *By Rain Action*

Rain is really a weak acid because it dissolves oxygen and carbon dioxide as it falls through the air. Some minerals especially carbonates are dissolved out of rocks by rain-water. These rocks are therefore weakened and begin to break up. Chemical weathering is most active in limestone rocks the surface of which becomes weathered into deep narrow grooves called *grikes* which are separated by flat or round topped ridges called *clints*. The rain-water enters the limestone via the joints which become enlarged to form clints.

In humid tropical countries chemical weathering is very active.



WEATHERING OF LIMESTONE ROCKS

II *By Plants and Animals*

Bacteria in the presence of water break down certain minerals in the soil, and all plants absorb minerals from the soil. Decaying vegetation produces organic acids which cause a further break-down of minerals. All these actions help to weaken and break up the rocks.

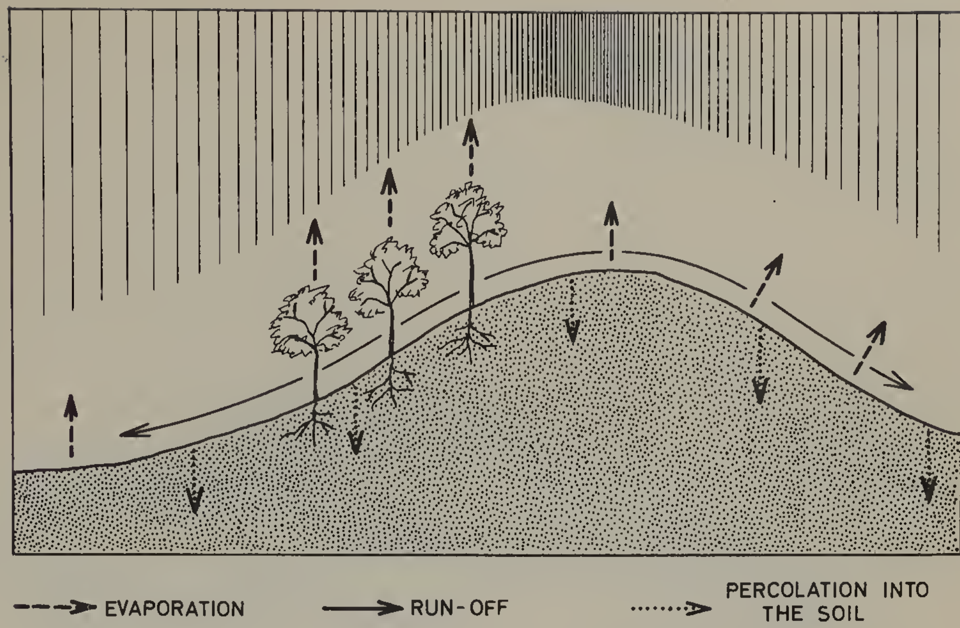
Note Chemical weathering takes place in all regions where there is rain, but it is most marked in wet regions which have high temperatures. Physical weathering takes place in all regions where there are changes in temperature but it is most marked in the hot deserts which have a large daily temperature range.

Desert Screes near St. Catherine's Monastery in Sinai

Underground Water

When rain falls some of it *runs off* the surface forming streams and rivers; some of it *evaporates* directly, or indirectly via plants; some of it soaks into the surface rocks.

The amount of run-off, evaporation and percolation depends upon the nature of the rocks, the slope of the land and the climate. Run-off on steep slopes is greater than on gentle slopes; evaporation in dry climates is greater than in humid climates, and water percolates into sands more easily than into granites.



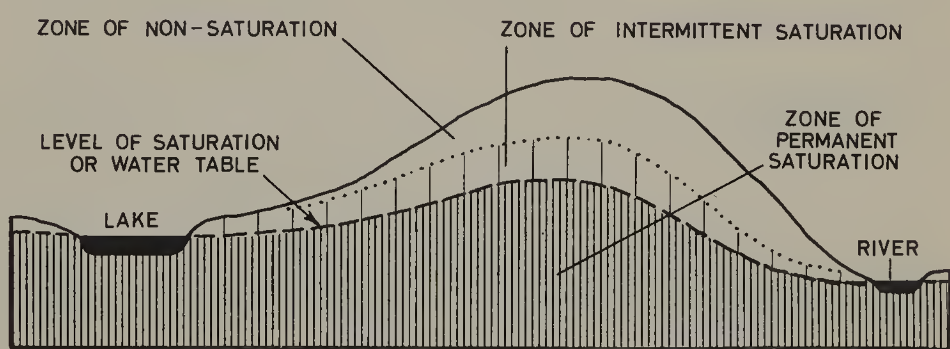
How Water enters into the Rocks

Water will enter rocks which are *porous* (i.e. rocks having small air spaces, e.g. sandstone) or rocks which are *pervious* (i.e. rocks having joints or cracks, e.g. granite). Rocks which allow water to pass through them are said to be *permeable*. Sandstone is a permeable rock. Rocks which do not allow water to pass through them are said to be *impermeable*. Clay is an impermeable rock.

Note Clay is porous (water enters it), but it is impermeable (water will not pass through it).

The Water Table or the Level of Saturation

Water entering the surface rocks moves downward until it comes to a layer of impermeable rock when further downward movement ceases. There are three water zones below the surface:



(i) *The zone of permanent saturation.* The pores of the rocks of this zone are always filled with water.

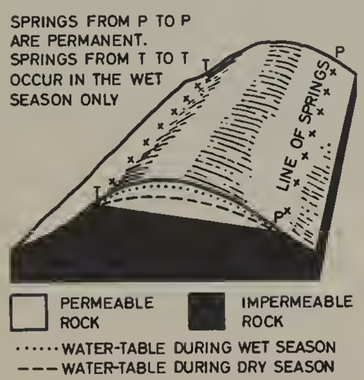
(ii) *The zone of intermittent saturation.* The pores of the rocks of this zone contain water only after heavy rain.

(iii) *The zone of non-saturation.* This lies immediately below the surface. Water passes through but never remains in the pores of the rocks of this zone.

Springs

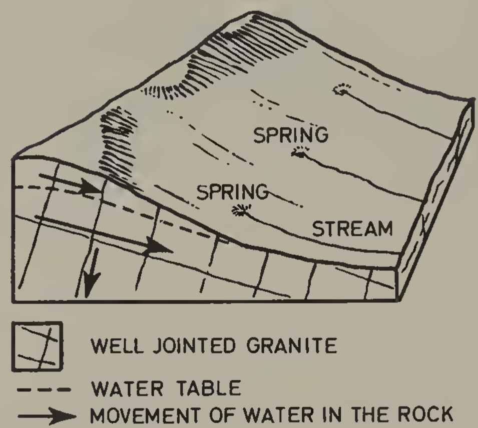
When water flows naturally out of the ground it is called a *spring*. There are many types of springs. Here are some of the more common ones.

I A permeable rock lying on top of an impermeable rock in a hill.



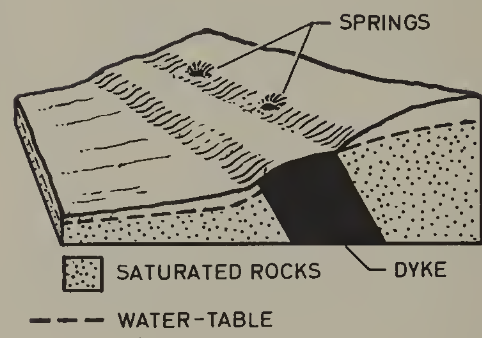
This diagram shows two lines of springs which occur where the junction of the two rock layers meets the surface. Notice that one line of springs is temporary.

II Well-jointed rocks forming hilly country produce springs.



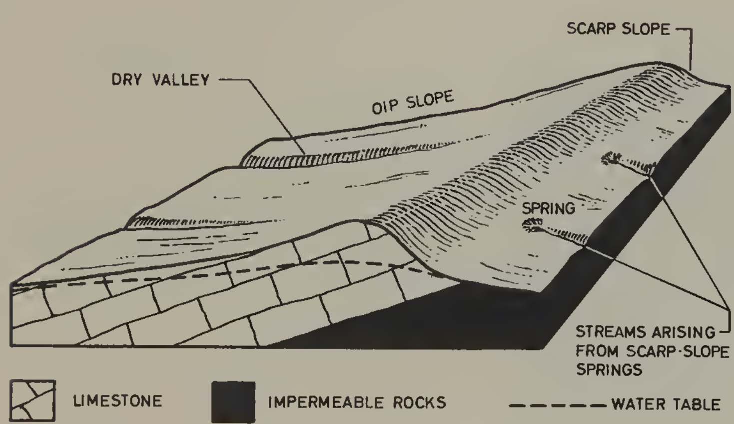
Water enters the rocks via the joints. Springs frequently occur where the water table meets the surface.

III The impounding of water by a dyke can give rise to springs.



If a dyke cuts across a layer of permeable rock then the water on the up-slope side of the dyke is impounded. The water table here rises and it gives rise to springs where it meets the surface.

IV Chalk or limestone escarpments which overlie impermeable rocks give rise to springs.

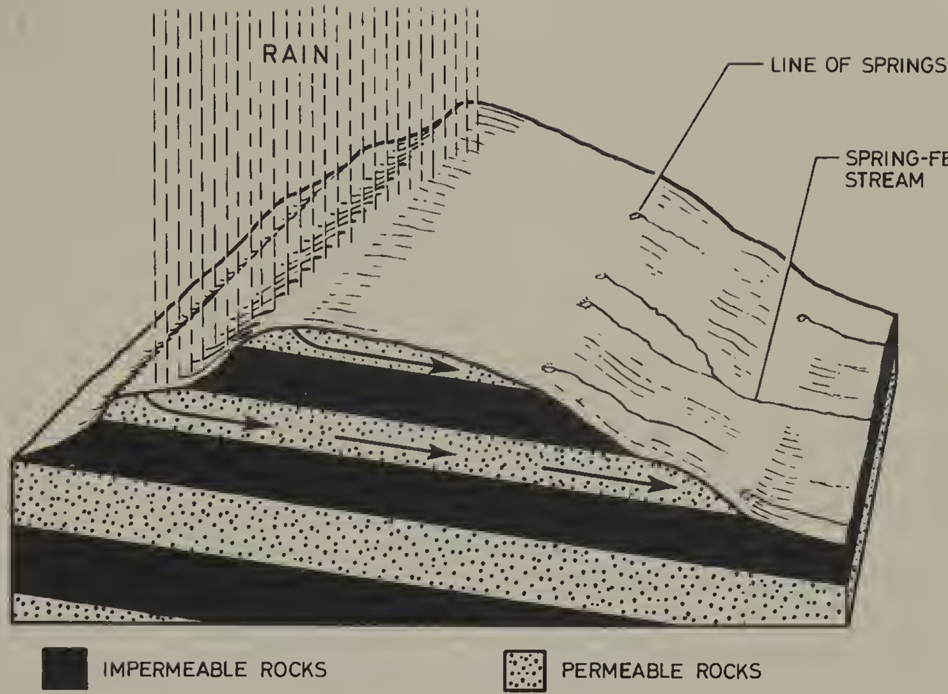


On the dip slope of cuestas such as the North Downs there are many dry valleys along which streams once flowed. These valleys are now dry because the level of the water table has fallen. The valleys are called dry valleys. After a prolonged period of heavy rain the water table sometimes rises high enough to allow a seasonal flow of water. This is called a bourne and an example of where it occurs is in the Caterham Valley near Croydon.

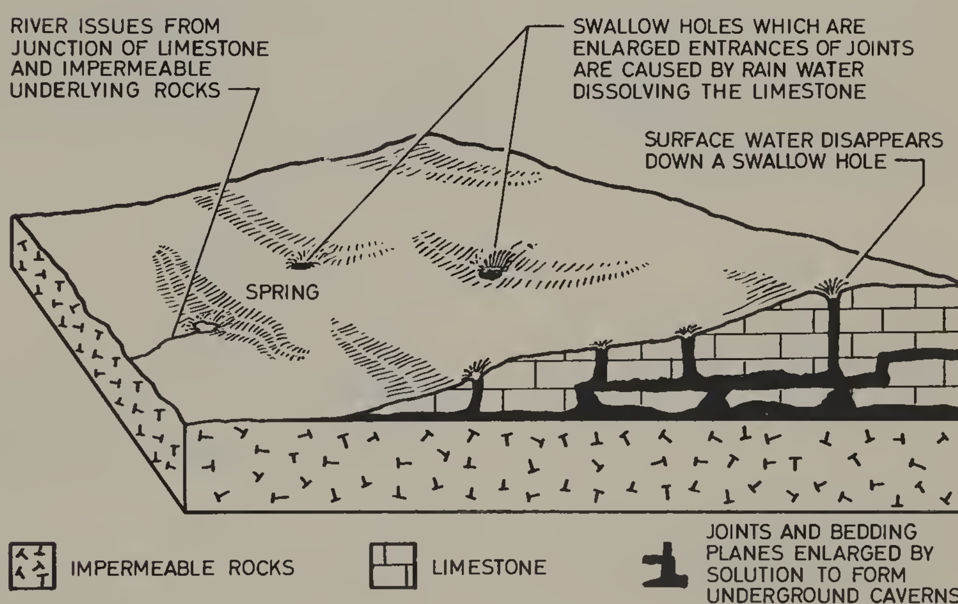
Usually two lines of springs occur, one at the foot of the scarp slope and the other on the dip slope. Since there is little or no surface drainage in limestone or chalk regions, settlements often become located near to the springs.

V Gently sloping alternate layers of permeable and impermeable rocks often produce springs. Rain falling on the exposed ends of the permeable rock layers soaks down the sloping bedding planes and finally comes out as springs. The springs are sometimes in lines.

VI Numerous springs occur where the junction of limestone rocks and underlying impermeable rocks meets the surface.



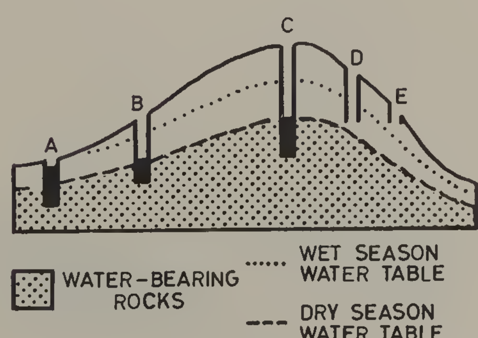
Limestone regions rarely have surface drainage. Both the rain and streams entering the region work their way by solution into the limestone rocks. Some joints become enlarged to form swallow holes. If the limestone rocks rest on impermeable rocks then this water will reach the surface again where the two rock types meet the surface. The water may issue out as streams or springs. Inside the limestone underground streams dissolve the rocks and form huge caverns.



Wells

A well is a hole sunk in the ground to below the water table. Water then seeps out of the rocks into the well.

Wells which are sunk far below the water table always contain water (A, B and C). Wells sunk only just below the water table often go dry in periods of drought when the water table falls (D). If a well is not sunk below the water table it will contain no water (E).

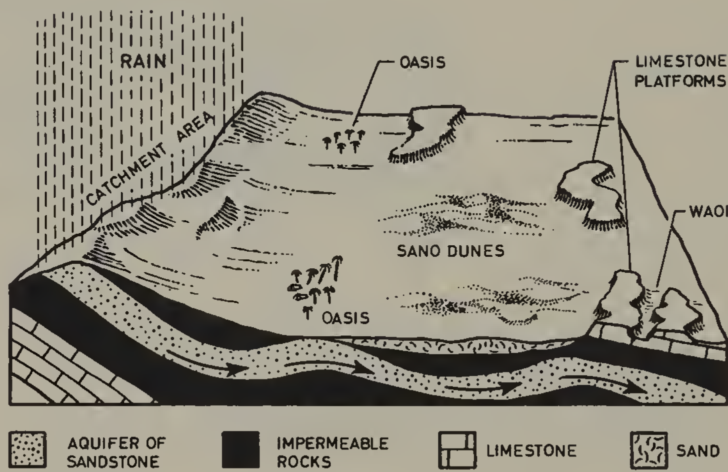


Artesian Basins and Artesian Wells

Artesian Basin

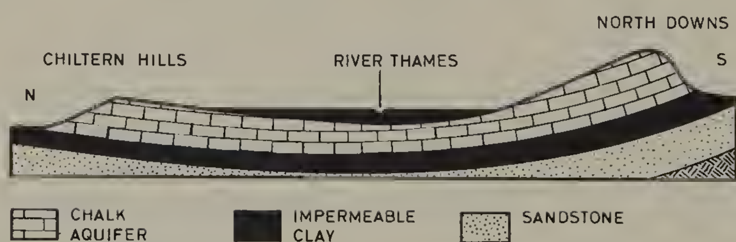
An *artesian basin* consists of a layer of permeable rock lying between two layers of impermeable rock such that the whole forms a shallow syncline with one or both ends of the permeable rock layer exposed on the surface. Rain water enters the permeable layer at its exposed ends. This layer becomes saturated with water and is called an *aquifer*. *Western Australia*, the *Sahara Desert* and parts of North America from *Saskatchewan* to *Kansas* are underlain by extensive artesian basins.

The diagram on the right shows a part of the artesian basin of the Sahara Desert. In places the aquifer bends up towards the surface and wind erosion sometimes exposes it. When this happens pools of water occur and these are called *oases* (sing. *oasis*). If the aquifer is near to the surface wells can be sunk. This is often done. Notice some typical hot desert erosional and depositional features, e.g. rock platforms, wadis and sand dunes. Also notice that the exposed part of the aquifer which receives the rain is called the catchment area.



Section across part of the Sahara Desert

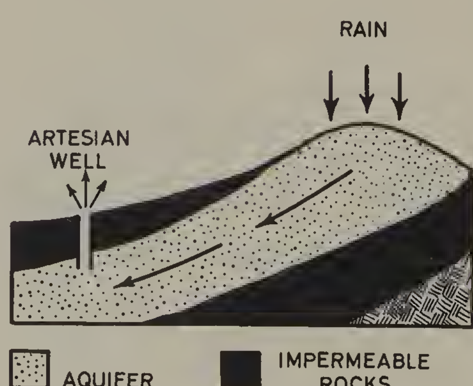
The London Basin consists of a shallow syncline formed of chalk which lies between layers of clay. In some parts the water table has fallen by as much as 100 feet during the last 50 years. One reason for this is that Waterboards and industries have taken so much water from the numerous wells sunk in the chalk aquifer.



Section across the London Basin

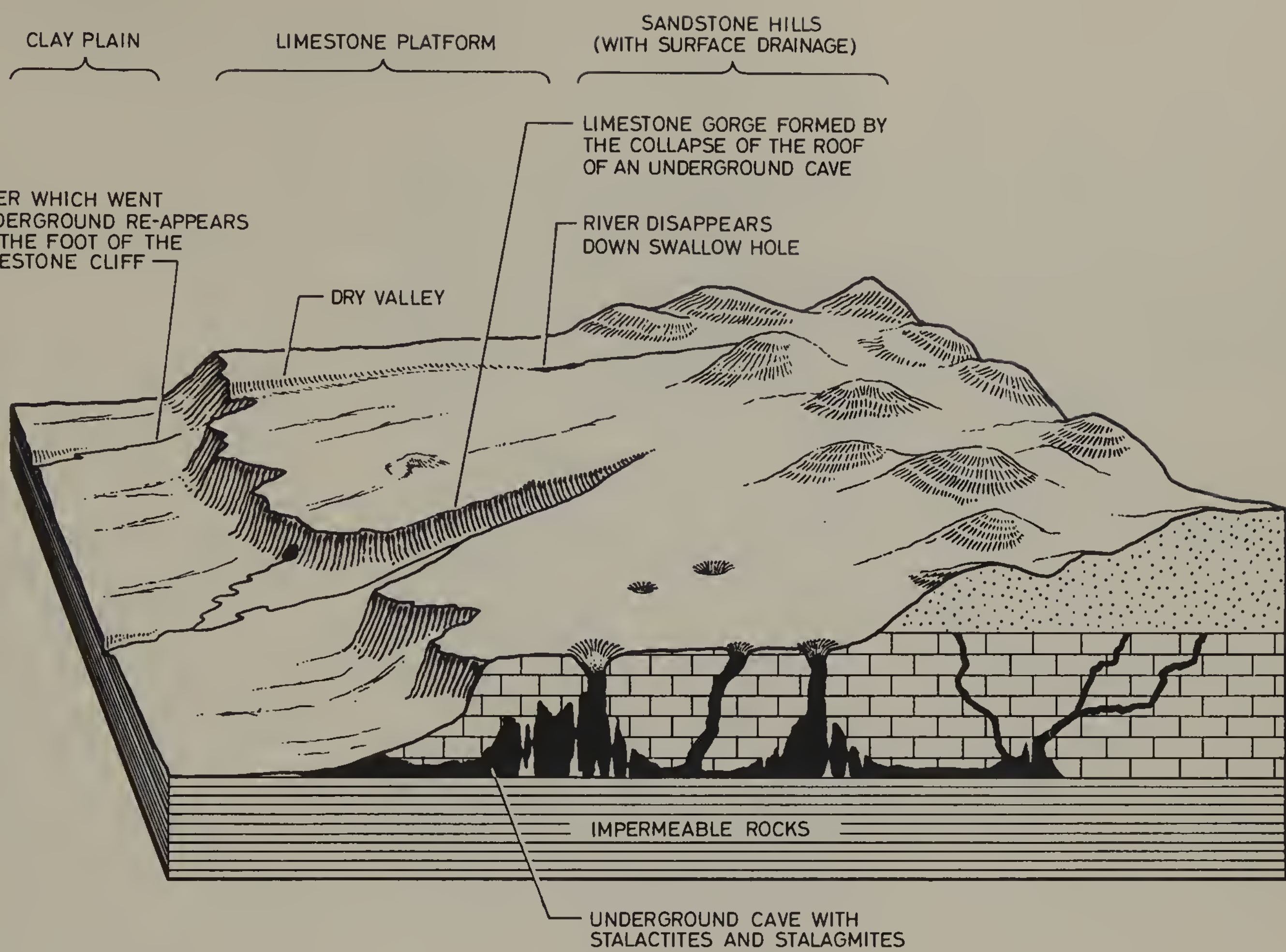
Artesian Well

If a well is sunk in the aquifer of an artesian basin and the pressure of water is sufficient to cause the water to flow out of it, then the well is called an *artesian well*.



Drainage Features in a Limestone Region

Limestone Landscape



Limestone consists chiefly of calcium carbonate which is insoluble. The carbon dioxide which rain-water absorbs from the air turns the carbonate into bicarbonate which is soluble. Thus rain-water and rivers remove limestone in solution.

$$CaCO_3 + CO_2 + H_2O = Ca(HCO_3)_2$$

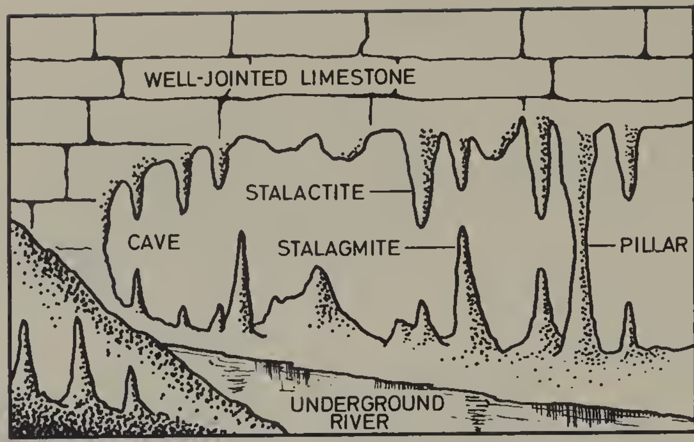
Limestone is a well-jointed rock and both the joints and bedding planes soon become opened up by solution. Entrances to joints are widened to form vertical openings called *swallow holes* and surface rivers frequently disappear down these. When rivers go underground they open up the joints and bedding planes by both solution and erosion and form underground *caves* and *caverns*. Some of these are of great size, e.g. *Carlsbad Cave* (New Mexico) is 4,000′ long, 600′ wide and 300′ high. *Stalagmites* and *stalactites* develop in these caves and sometimes they join together to form *natural columns* or *pillars*.

Rivers which disappear underground when entering a limestone region reappear on the surface again where the junction of the limestone and the underlying impermeable rocks meet the surface. Dry, gorge-like valleys often mark the former courses of such rivers and these occur between the point of disappearance and the point of emergence (diagram, page 47). The former course over the limestone in European regions was probably made possible by the frozen subsoils in Glacial Times. Dry waterfalls also occur in these valleys, especially where the rivers once crossed limestone escarpments.

Other surface features include *clints* and *grikes*, which have already been discussed, extensive bare limestone outcrops and thin, infertile soils. Limestone regions usually contain very little vegetation, although in hot humid countries like Malaya dense jungle often covers large areas of the limestone.

Chief Limestone Regions of the World

1 Karst Region of Yugoslavia.
2 The Causses of South Eastern part of the Central Massif of France.
3 The Kentucky Plateau of the U.S.A.
4 The Yucatan Peninsula of Central America
5 The Florida Peninsula of the U.S.A.
6 The Pennine District of England.



INTERIOR VIEW OF A LIMESTONE CAVE

Value of Ground Water to Man

1 Springs and wells have played an important part in the siting of settlements in many regions all over the world.
2 In some regions, e.g. hot deserts and semi-arid plains, settlement is only possible by utilising the ground water. When this is too deep to be tapped, settlement does not take place.
3 In Southern Algeria there is a limestone plateau which is 2,000′ above sea level. The Chebka people who live there have dug wells to tap the underground water. The water is used for irrigating the land and the wells have given rise to numerous oases.
4 The *Soafas* (people of the Suf) who live on the borders of Tunis and Algeria use artesian water which lies near to the surface. This water maintains many oases which cultivate date palms.
5 The great artesian basins which underlie Queensland, New South Wales and parts of South Australia have an area of 600,000 square miles. Water taken from the many wells which tap the aquifer of the basins is too salty for irrigation but is used for watering large herds of cattle.
6 Similar artesian basins underlie parts of North America from Kansas to Saskatchewan and wells here raise water for use in cattle ranching.
7 Wells play an important part in agriculture in the Indo-Gangetic Plain of the Indian Sub-continent in the dry season. The water is used for irrigation.

Rain Action

Rain action is an aspect of erosion because it involves movement. It is most marked in semi-arid regions because these have little or no vegetation and the rains, though infrequent, are torrential. Rain action produces many types of features of which the following are the most common.
1 *Gully* 2 *Earth Pillar* 3 *Soil Creep* 4 *Landslide*

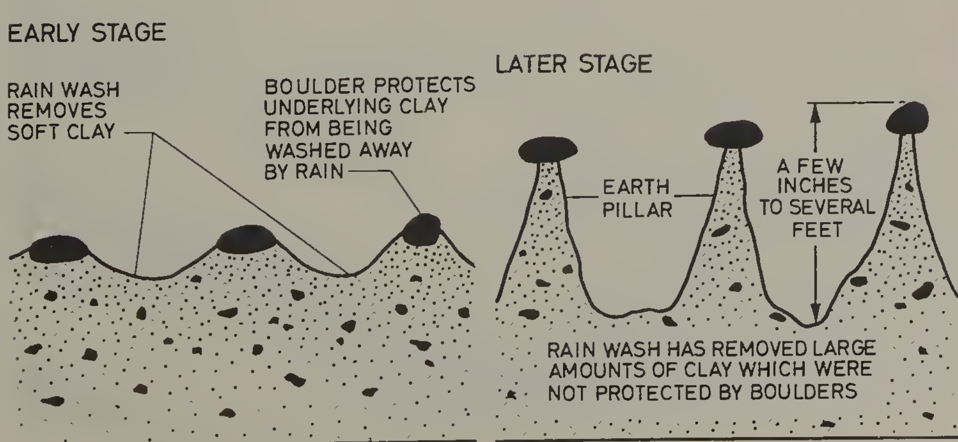
Badlands of Dakota in U.S.A. The hill sides are deeply gullied

Gully
Rain which falls on gently sloping land which has little or no vegetation moves downhill as a sheet of water. The slope is quickly eroded into deep grooves called *gullies.* They develop on a small scale on embankments and cuttings and also tip heaps. They develop on a large scale in semi-arid regions where the landscape becomes cut up into gullies and ridges of all shapes and sizes, as in the *Badlands* of the Dakotas (U.S.A.).

The influence of rain wash on soil erosion will be discussed in a later section.

Gully Erosion in a road-side laterite bank in Kuala Lumpur

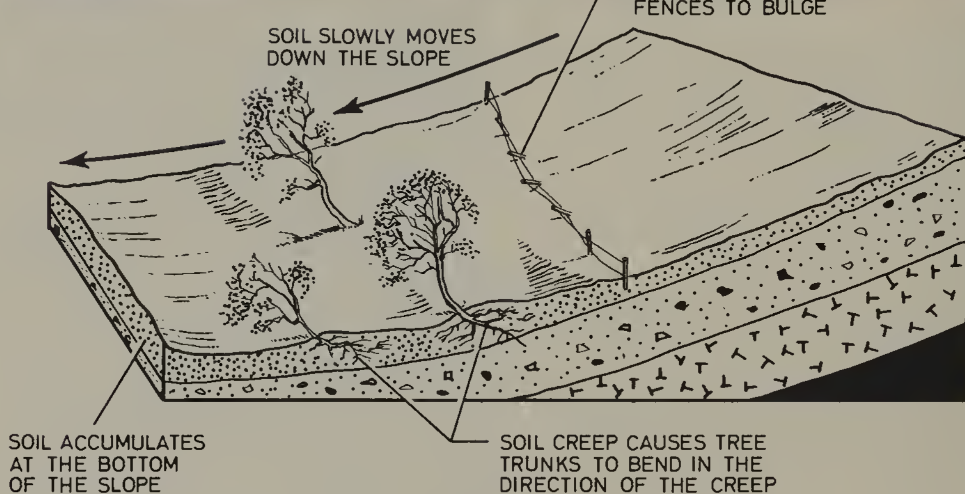
Earth Pillar
When rain falls on slopes made of clay and boulders, the clay is rapidly removed except where boulders protect it. The upstanding parts capped by boulders are called *earth pillars.*



Earth Pillars in Upper Rhone Basin
The columns of soft clay are capped by boulders which protect the clay of the columns from erosion. However, the pillars are only temporary. In time they will be removed by erosion.

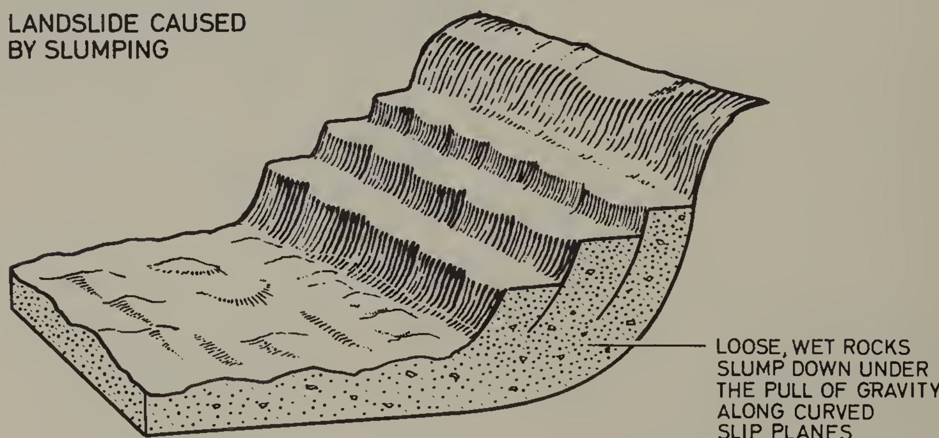
Soil Creep (slow movement)
On all sloping land there is a steady movement of the soil down the slope. Rain-water soaking into the soil slowly trickles down the slope and this causes a movement in the soil. Bulging fences and walls and outward bending tree trunks reflect this movement which is called *soil creep* (top diagram).

SOIL CREEP



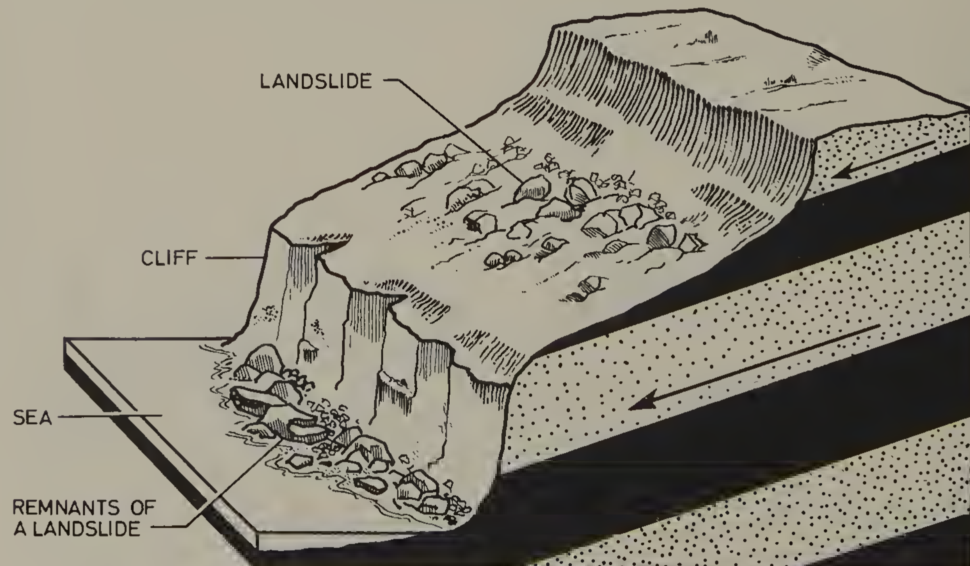
Landslide (sudden movement)
A *landslide* takes place when large quantities of loosened surface rocks slide down steep slopes which may be cliff faces, embankments, valley sides or railway cuttings. Landslides are caused by the lubricating action of rain-water and the pull of gravity which result in slumping or sliding.

LANDSLIDE CAUSED BY SLUMPING



Landslide caused by slumping
Slumping of this type takes place on steep slopes made of clay. It is especially common in cliffs of clay which are under wave attack.

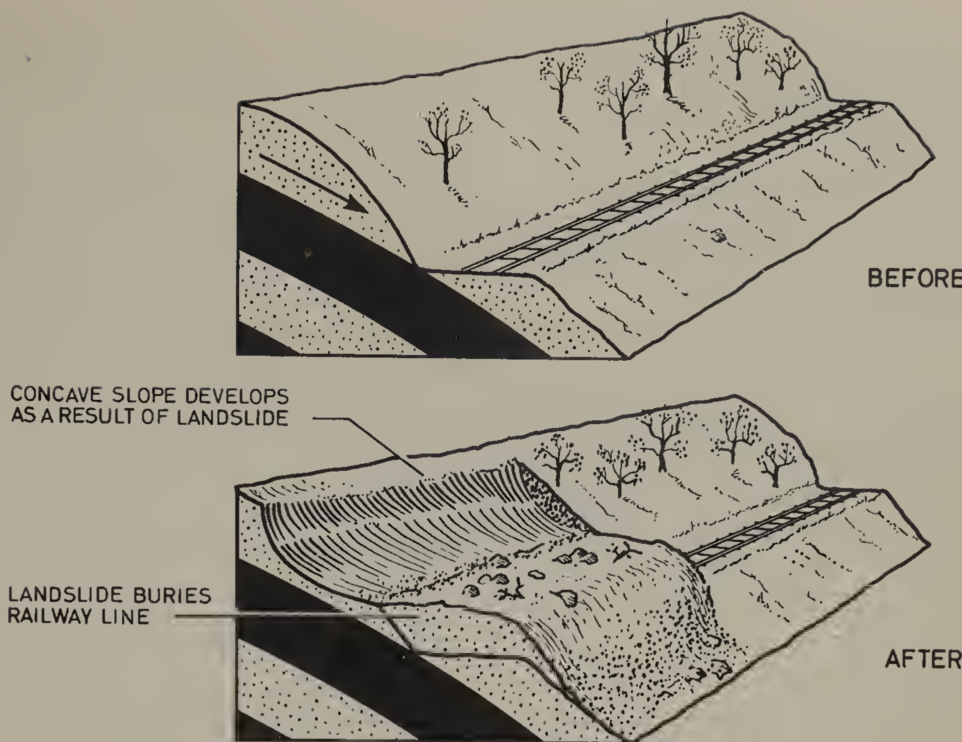
Landslide caused by sliding
The black arrows show both the place of lubrication and the direction of movement.



ROCKS DIP STEEPLY TOWARDS THE SEA

Landslide on a Railway Cutting

Landslides are very common on the sides of railway and road cuttings, especially in mountainous regions which have heavy falls of rain. In some regions frost action speeds up the process. Frozen soils and sub-soils on steep slopes become unstable when they thaw and the movement of water down the slope together with the pull of gravity triggers off a landslide.



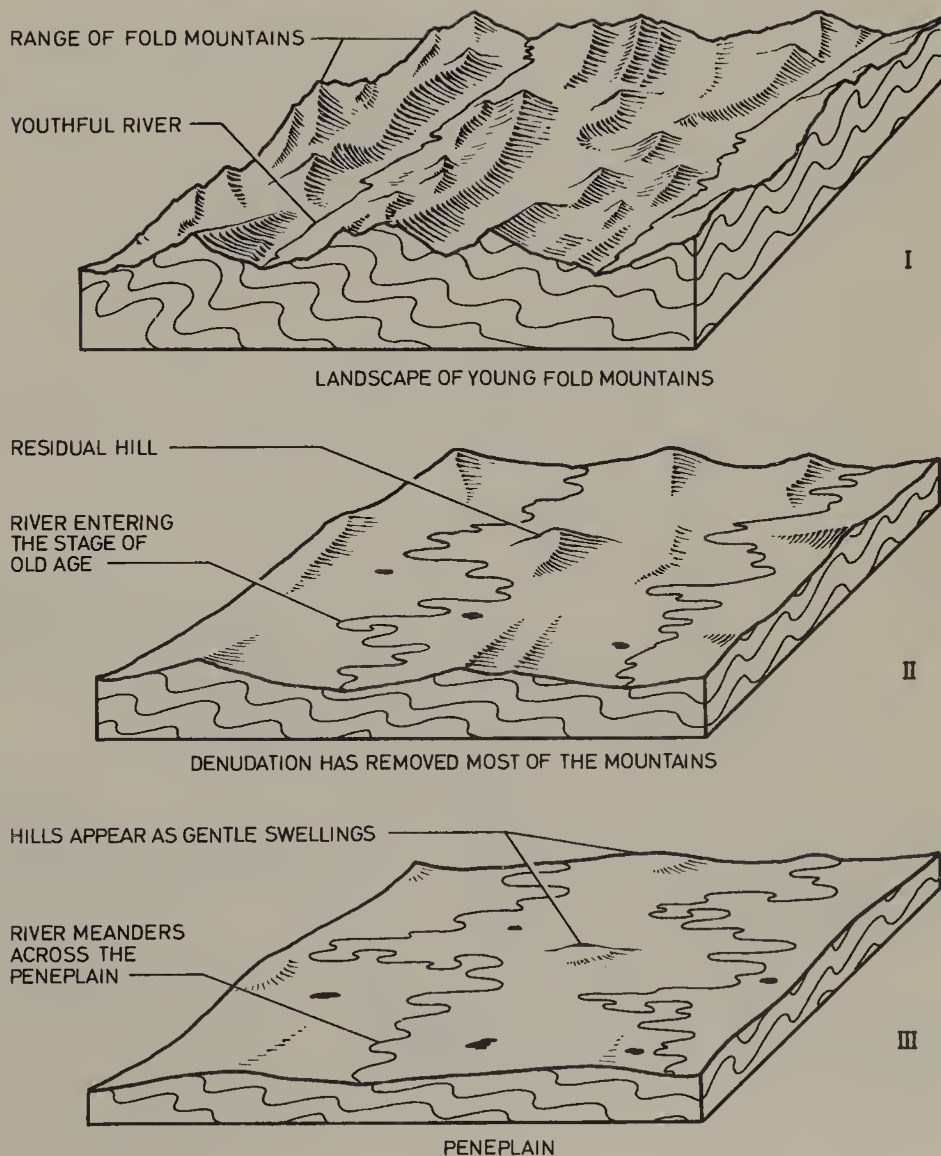
River Action and the features it produces

A river's *source* is the place at which it begins to flow. It may be in the melt waters of a glacier, e.g. the *Rhone* (France), or in a lake, e.g. the *Nile* (Africa), or in a spring, e.g. the *Thames* (England), or in a region of steady rainfall, e.g. the *Congo* (Africa). A river's *mouth* is the place where the river ends. This is usually in the sea, e.g. the *Amazon* (Atlantic), the *Niger* (Gulf of Guinea) and the *Indus* (Arabian Sea), although it may be in a lake, e.g. the *Volga* (Caspian), or in a salt swamp, e.g. the *Chari River* (Lake Chad) and the *Tarim River* (Lop Nor).

Rivers are one of the greatest sculpturing agents at work in humid regions. They carve out *valleys* in the highlands and as they do so they produce *peaks*, *ridges* and *hills*.

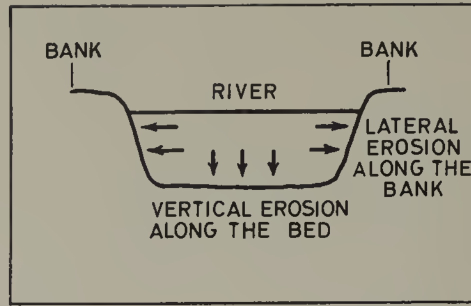
The material so removed is transported from the highlands and is deposited around them as gently sloping *plains*. A river thus does three types of work: it ERODES; it TRANSPORTS; and it DEPOSITS.

In process of time river erosion, transport and deposition turn the original surface into an almost level plain which is called a *peneplain*.



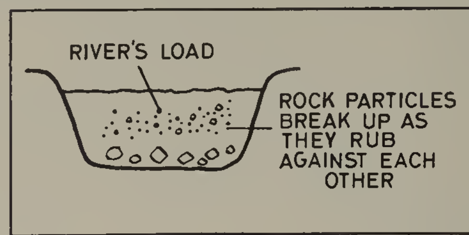
River Erosion, Transport and Deposition

The rock waste carried by a river is called its LOAD, and this is produced by weathering in the first instance.



Erosion

1 The load of a river rubs against the bed and sides of the river's channel and slowly wears these away. This is *corrasion*.
2 The river's load itself becomes broken into small pieces as it is carried along. This is *attrition*.
3 River water dissolves certain minerals, e.g. limestone. This is *solution*.



Transport A river carries its load in three ways:
1 It rolls large stones and boulders along its bed
2 Some minerals are carried in solution
3 Fine rock particles are carried in suspension.

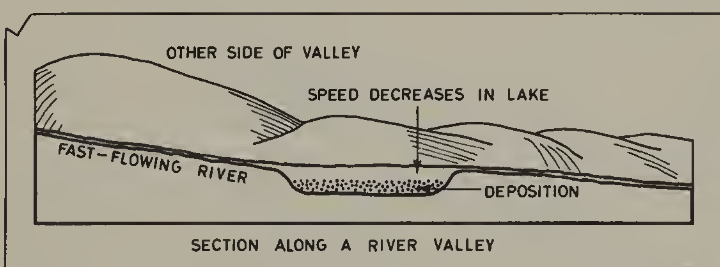
Note If there are two rivers of the same volume the faster flowing of the two will be able to transport the greater load.

Deposition A river drops its load when either its volume or its speed decreases.

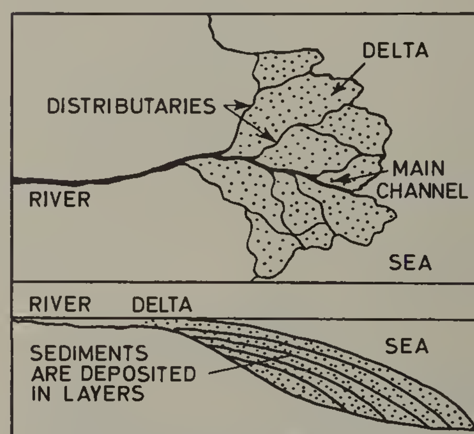
A river's volume decreases:
1 When it enters an arid region (especially a hot one)
2 When it crosses a region composed of porous rocks, e.g. sand and limestone
3 In the dry season or in a period of drought.

A river's speed decreases when it:

1 Enters a lake

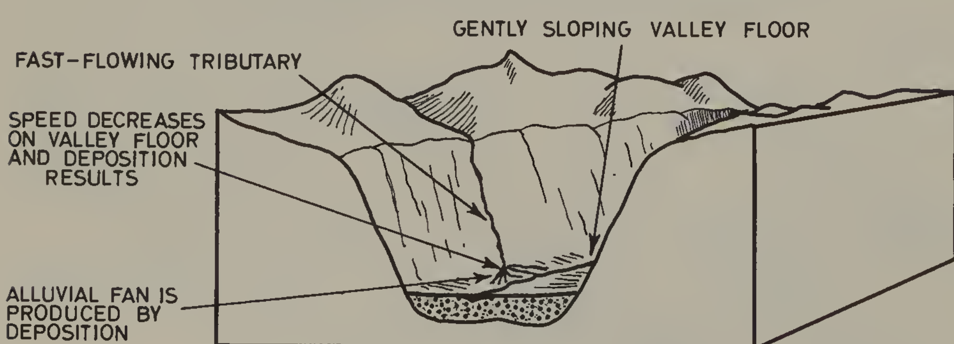


2 Enters the sea



NOTE: NOT ALL RIVERS BUILD A DELTA WHEN THEY ENTER THE SEA

3 Enters a flat or gently-sloping plain such as a valley bottom.

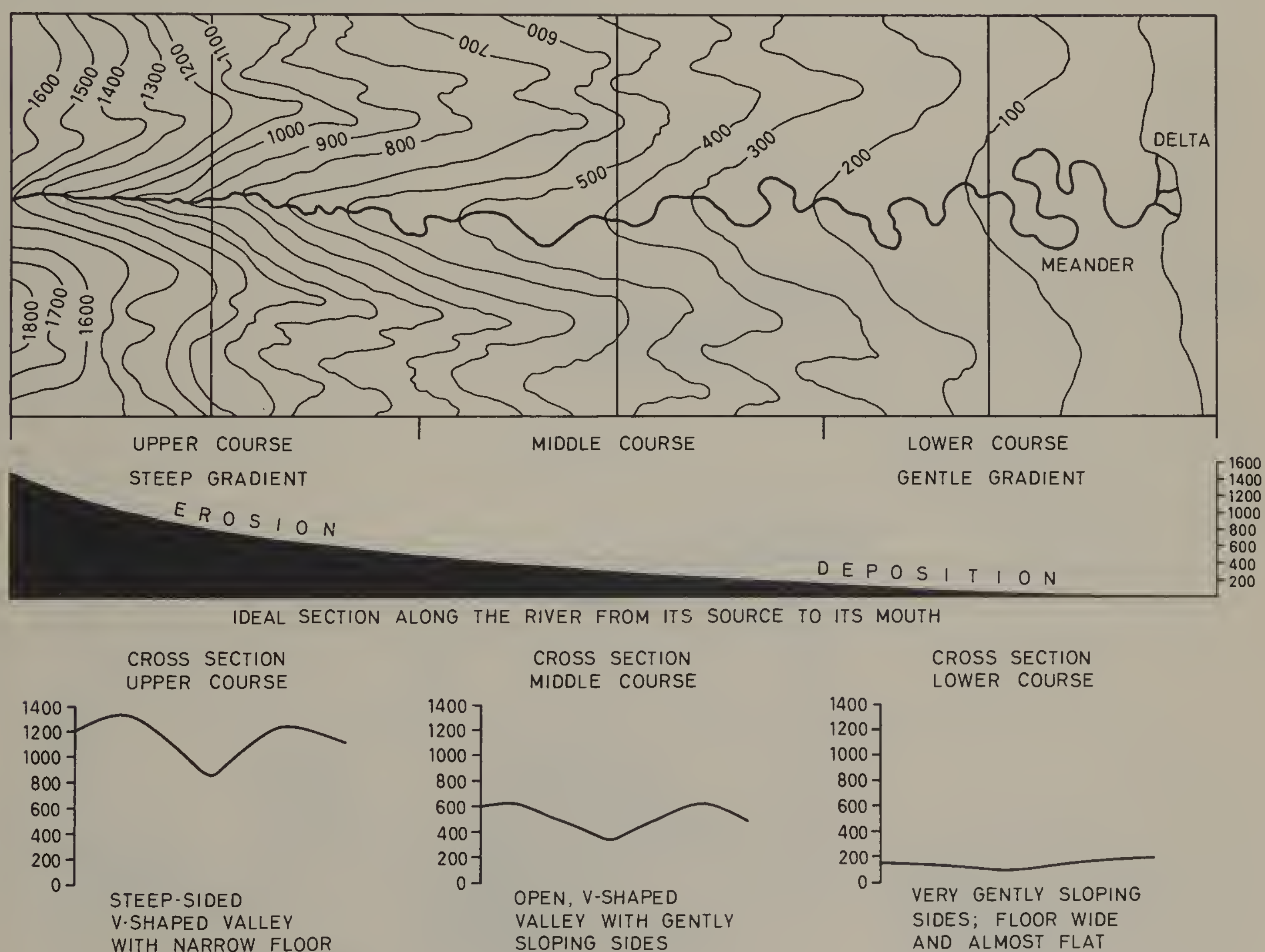


The Development of a River Valley

A river like an animal or a plant has a 'life-cycle'. In the beginning, when it is in the *stage of youth*, it flows quickly in a narrow, steep-sided valley whose floor is broken by pot-holes and waterfalls. As time passes denudation widens the valley and lowers its floor. Now that the gradient is reduced the river flows more slowly and the initial bends that it had, because of the nature of its valley floor, become more pronounced. It is now in the *stage of maturity*. As denudation continues the valley is opened out more and more. The gradient is further reduced and deposition now becomes active. Layers of sediments are dropped by the river and these ultimately extend over the entire floor of its valley where they build up a gently sloping plain called a *flood plain*. The river slowly wanders in great *meanders* or loops across this plain and often it becomes divided into many channels by its own deposition. The river is now in the *stage of old age*. Deposition within the mouth of an old river sometimes builds up a triangular-shaped piece of land called a *delta*.

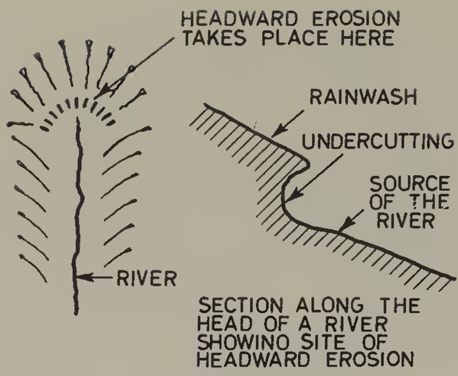
Note Youthful Stage is often called Torrent Stage. Mature Stage is often called Valley Stage. Old Age Stage is often called Plain Stage.

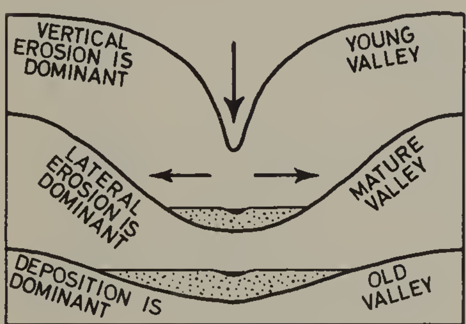
Many river valleys such as those of the *Nile*, *Indus* and *Irrawaddy* contain all three stages. The torrent or *upper course* represents the stage of youth; the valley or *middle course* represents the stage of maturity, and the plain or *lower course* represents the stage of old age.



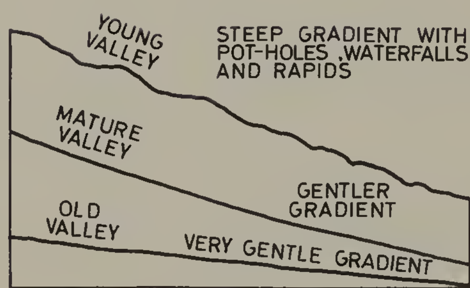
A river valley grows in length by *headward erosion*. Rain wash, soil creep and undercutting at the head of a river combine to extend the valley up the slope.

A river's valley is deepened by *vertical erosion* and widened by *lateral erosion*. The former is entirely a river process; the latter is effected by weathering on the valley sides and by the river on the river banks. When a river's gradient is steep, i.e. when it is in the stage of youth, vertical erosion is dominant. When a river's gradient is very gentle, i.e. when it is in the stage of old age, there is little erosion and deposition is dominant. In a mature valley lateral erosion is dominant. The diagrams below show sectional views of young, mature and old valleys.





CROSS SECTIONS

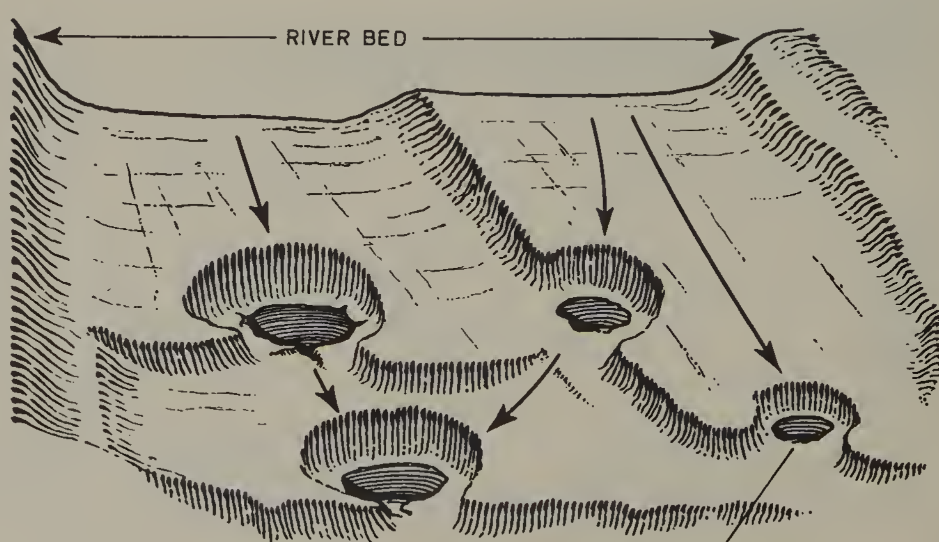


LONG SECTIONS

Over 1 in 10 Youthful (Torrent) Stage.
Between 1 in 10 and 1 in 100 Mature (Valley) Stage.
Under 1 in 100 Old Age (Plain) Stage.

The Characteristic Features of a Youthful Valley

1 Deep, narrow valley (V-shaped) } For diagrams
2 Valley has a steep gradient (river is fast-flowing) } see previous page
3 Pot-holes
4 Interlocking spurs
5 Waterfalls and rapids



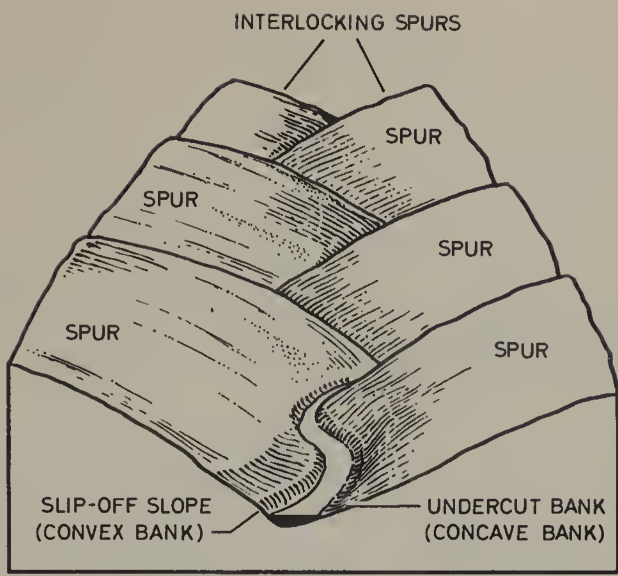
SWIRLING WATER FALLING INTO A SLIGHT DEPRESSION TURNS IT INTO A CYLINDRICAL HOLE CALLED A POT HOLE

3 Pot-holes

The water of a fast-flowing river swirls if the bed is uneven. The pebbles carried by a swirling river cut circular depressions in the river bed. These gradually deepen and are called *pot-holes*. Much larger but similar depressions form at the base of a waterfall. These are called *plunge pools*.

4 Interlocking Spurs

Vertical erosion rapidly deepens the valley. The river twists and turns around obstacles of hard rock. Erosion is pronounced on the concave banks of the bends and this ultimately causes spurs which alternate on each side of the river to *interlock*. The undercut concave banks often stand up as *river cliffs*. On the opposite convex banks there is little or no erosion. The banks form gentle *slip-off-slopes*.



V-SHAPED VALLEY WITH INTERLOCKING SPURS

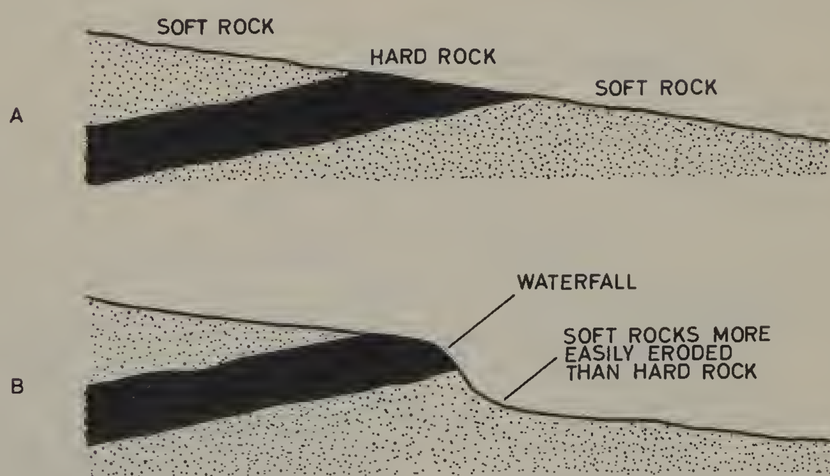
5 Waterfalls and Rapids

These occur where the bed of a river becomes suddenly steepened. Waterfalls are of two types:

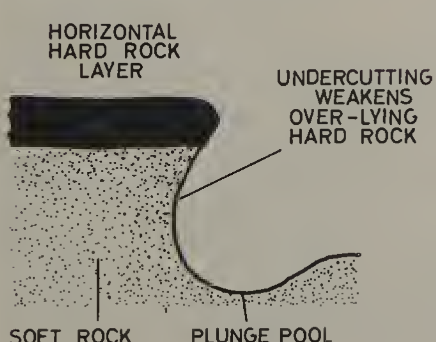
(i) Those caused by differences in rock hardness into which the river is cutting.
(ii) Those caused by uplift of the land, lava flows and landslides, etc.

Waterfalls caused by Differences in Rock Hardness

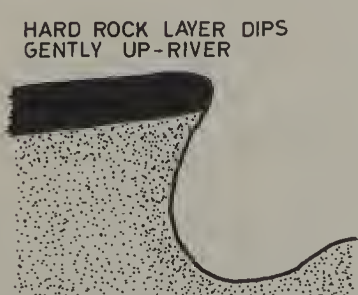
Development of a Waterfall
When a layer of hard rock (rock which resists erosion) lies across a river's course, the soft rocks on the down-stream side are more quickly eaten into than is the hard rock. The river bed is thus steepened where it crosses the hard rock and a *waterfall* or a *rapid* develops. A waterfall arises when the hard rock layer is: (i) horizontal, (ii) dips gently up-stream, or (iii) is vertical.



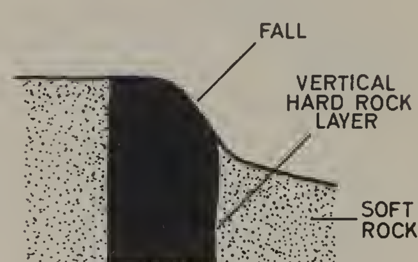
(i) Rock layer is horizontal



(ii) Rock layer dips up-stream

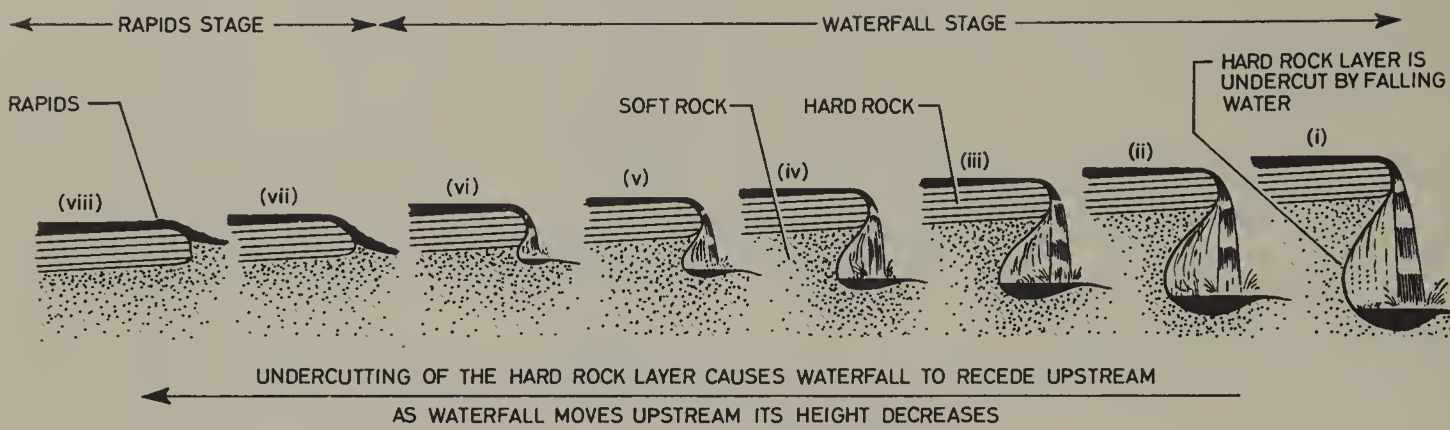


(iii) Rock layer is vertical

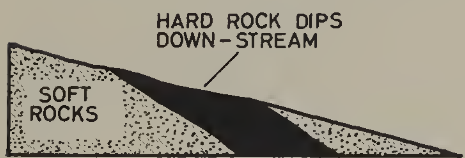


A *rapid* develops when:

1 A waterfall of types (i) and (ii) above retreats up-stream.



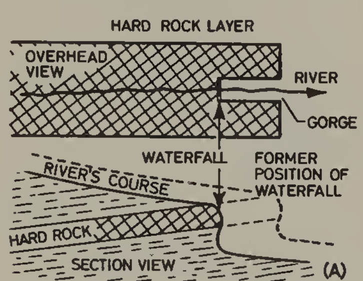
2 A hard rock layer dips down-stream.

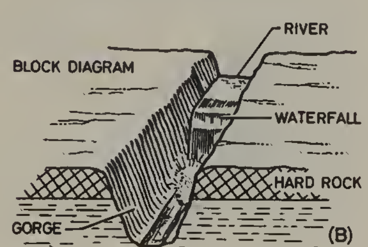


Young Valleys of Special Interest

Some valleys have very steep sides and are both narrow and deep. These are called *gorges*.

A gorge often forms when a waterfall retreats up-stream. The diagrams below show how this takes place. One of the most impressive gorges formed in this way lies below the Victoria Falls.





Some Common Waterfalls and Rapids

1	*Gersoppa Falls* (830′)	Western Ghats of India (in the wet season it is the greatest fall in the world).
2	*Kaieteur Falls* (740′)	Potaro River (British Guiana): 5° 0′N; 59° 0′W.
3	*Aughrabies Falls* (450′)	Orange River (South Africa): 28° 49′S; 20° 22′E.
4	*Victoria Falls* (360′)	Zambesi River (Rhodesia): 17° 49′S; 25° 51′E. The gorge below the Falls is 60 miles long.
5	*Niagara Falls* (170′)	Between Lakes Erie and Ontario: 43° 7′N; 79° 1′W. The gorge below the Falls is 7 miles long.
6	*Livingstone Falls* (900′)	Congo River: 5° 0′S; 14° 15′E. The Falls are formed by 32 rapids.
7	*Nile Cataracts*	Between Aswan and Khartoum.

The gorge below the Victoria Falls on the River Zambesi (Rhodesia). It is normally obscured by spray from the waterfall

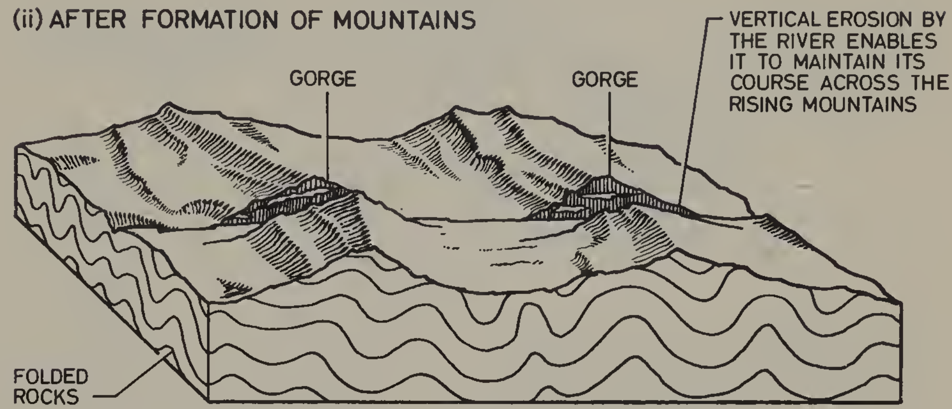
A gorge will also form when a river maintains its course across a belt of country which is being uplifted. Only very powerful rivers are able to do this.

The diagrams on the right show how this comes about. Notice that only parts of the region crossed by the river are uplifted and *not* the whole region. If the latter happened a gorge would develop along the entire length of the river.

The Indus, Brahmaputra and the headwaters of the Ganges have cut deep gorges in the Himalayas. The Indus gorge in Kashmir is 17,000′ deep. The Columbia River has also cut a gorge across the Cascades in North America.

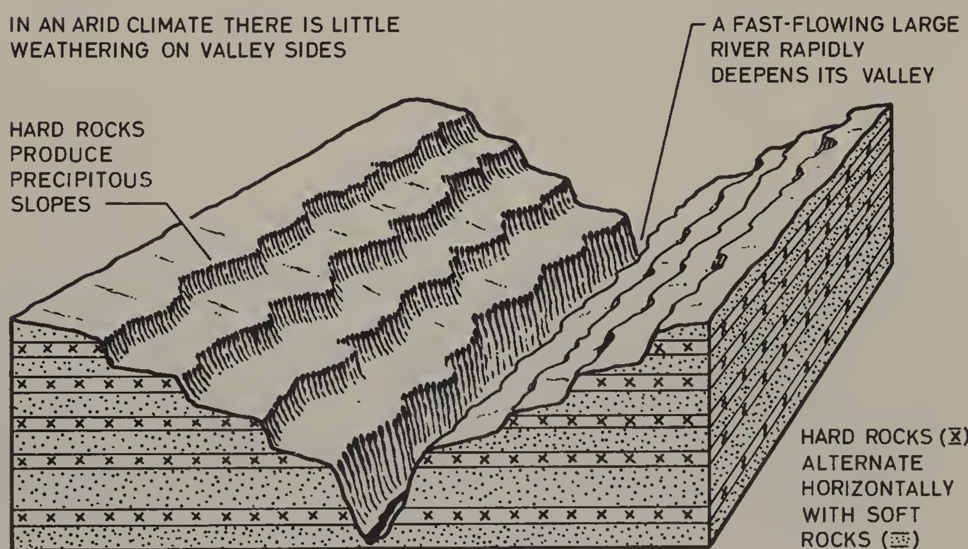
(i) BEFORE FORMATION OF MOUNTAINS

(ii) AFTER FORMATION OF MOUNTAINS



EARTH MOVEMENTS HAVE RESULTED IN THE FORMATION OF MOUNTAIN RANGES ACROSS THE RIVER'S COURSE

When a river flows across a plateau which is composed of horizontal and alternate layers of hard and soft rock, the valley it cuts will be deep and narrow. If the region is arid then there will be little weathering on the valley sides and the gorge will be very impressive. The Colorado River has cut a gorge one mile deep and 300 miles long into the Colorado Plateau (U.S.A.). Because of its size the gorge is called a *canyon*.

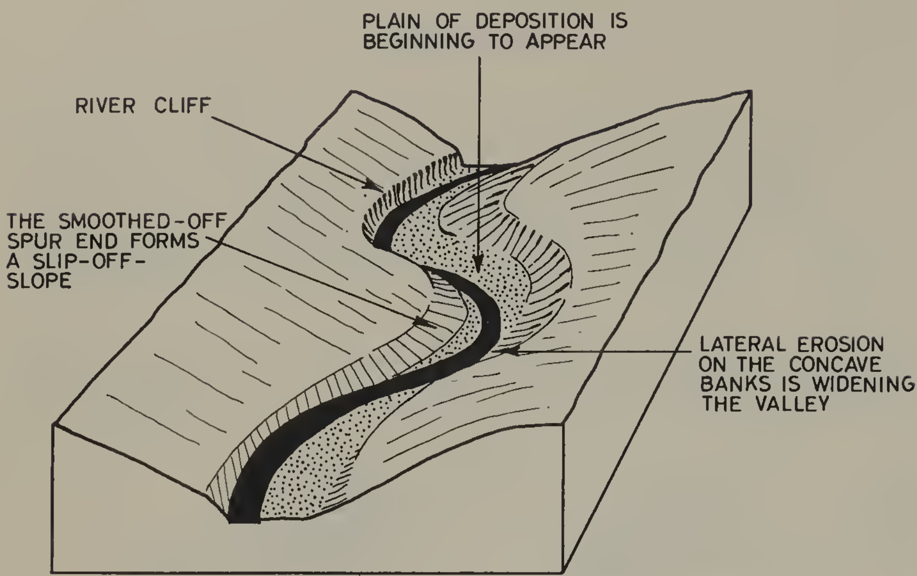


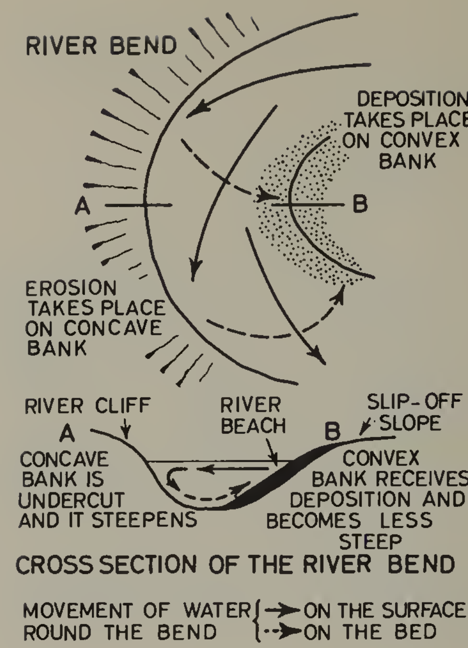
RIVER EROSION DEEPENS THE VALLEY MORE RAPIDLY THAN WEATHERING WIDENS IT

Characteristic Features of a Mature Valley

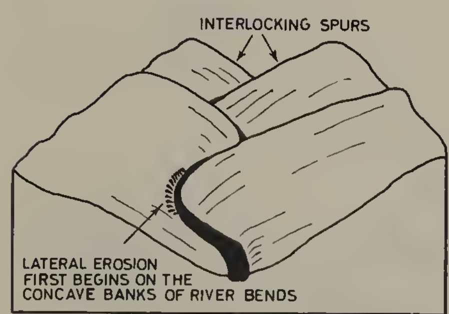
1. The valley has the shape of an open V in cross section.
2. The gradient is more gentle than in a young valley.
3. River bends are pronounced. The concave banks stand up as river cliffs; the convex banks slope gently as slip-off-slopes (smoothed ends of spurs).
4. Spurs are removed by lateral erosion. Their remains form a line of bluffs on each side of the valley floor.
5. The valley floor is wide and by the time the valley enters the stage of old age it is covered with a veneer of sediments.

River Action along the Banks and Bed of a River Bend

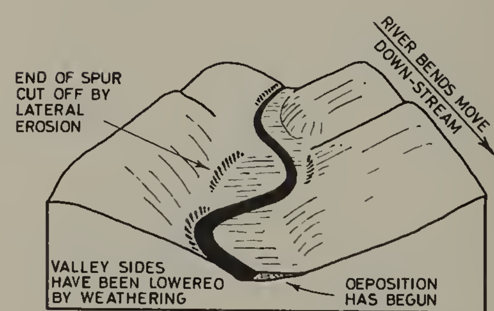




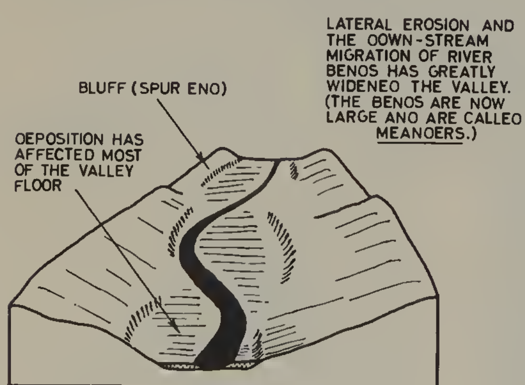
I The young valley has well-developed interlocking spurs. Lateral erosion on the concave banks has begun.



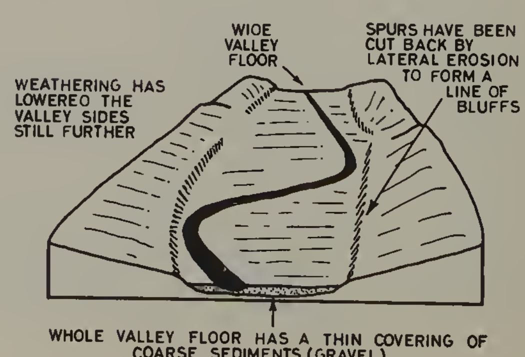
II Weathering has lowered the valley sides and lateral erosion has planed off the ends of the interlocking spurs. This has made the valley wider. Deposition on the convex banks is becoming important.



III The valley is now mature. The migration of the river bends down the valley has both widened it and straightened it. The ends of the spurs stand up as *bluffs*.



IV The valley is now fully mature and it is approaching the stage of old age. Lateral erosion has developed a wide valley whose floor is almost completely covered with layers of sediments. A *flood plain* is clearly being formed. The meander belt is as wide as the valley.

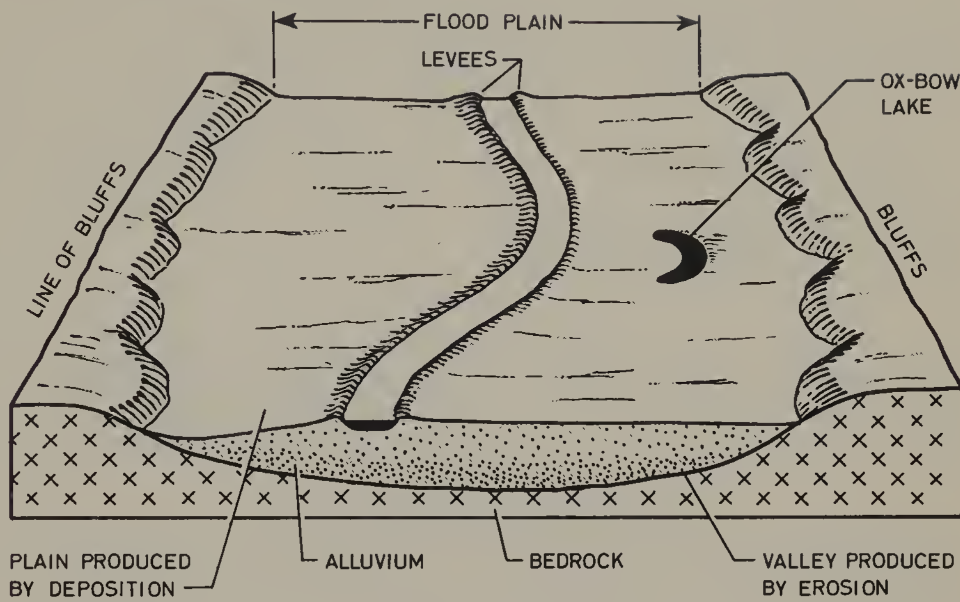


Characteristic Features of an Old Valley

1 The valley is broad, flat-floored and its gradient is gentle.
2 Sediments cover the valley floor forming a *flood plain* and this is often marshy.
3 Meanders are pronounced, *cut-offs* develop and these give rise to *ox-bow lakes*.
4 In its later development the river builds up its bed and banks with alluvium (the banks are called *natural levees*). The river thus flows between pronounced banks and above the level of the flood plain.
5 The river mouth sometimes becomes blocked with sediments and a *delta* forms.

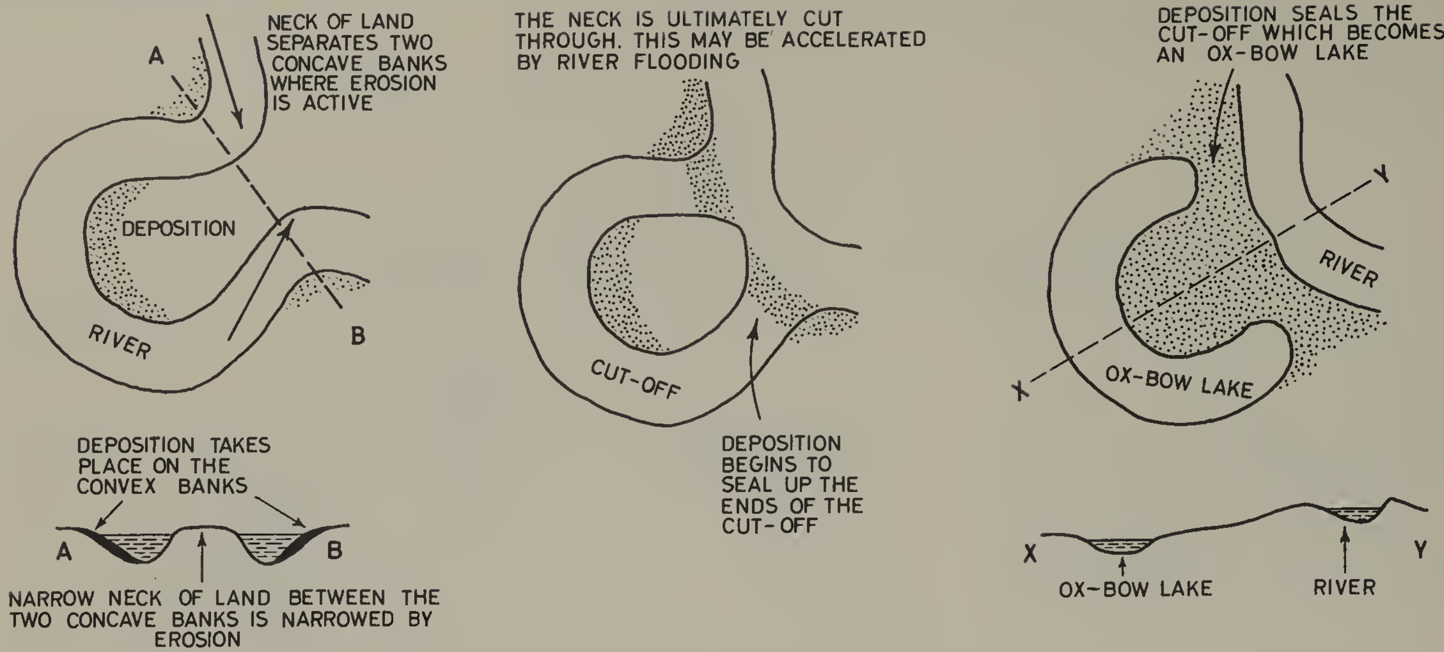
The Building of the Flood Plain

1 The valley floor is widened by lateral erosion (stage of maturity).
2 Deposition takes place on the convex banks of meanders and this produces river beaches. The whole valley floor ultimately receives deposition as meanders wander across it. This begins in the stage of maturity.
3 Fine silts and muds are deposited on the valley floor when the river floods and overflows its banks. This is the final process in the growth of the flood plain. Meanders still migrate down the valley and in doing so they cut terraces into the flood plain.



The Grand Canyon in U.S.A.

The Development of an Ox-bow Lake



An acute meander where a narrow neck of land separates two concave banks which are being undercut.

Erosion has broken through the neck of land. This often happens when the river is in flood. The meander has been cut off.

Deposition takes place along the two ends of the cut-off and it is eventually sealed off to form an *ox-bow lake.*

Note how the area of deposition along the convex banks is increasing. After the formation of the ox-bow lake the river bed and banks are steadily raised by deposition and ultimately the river lies above the level of the ox-bow lake. This is shown in the section under (iii)

Mekong Meander

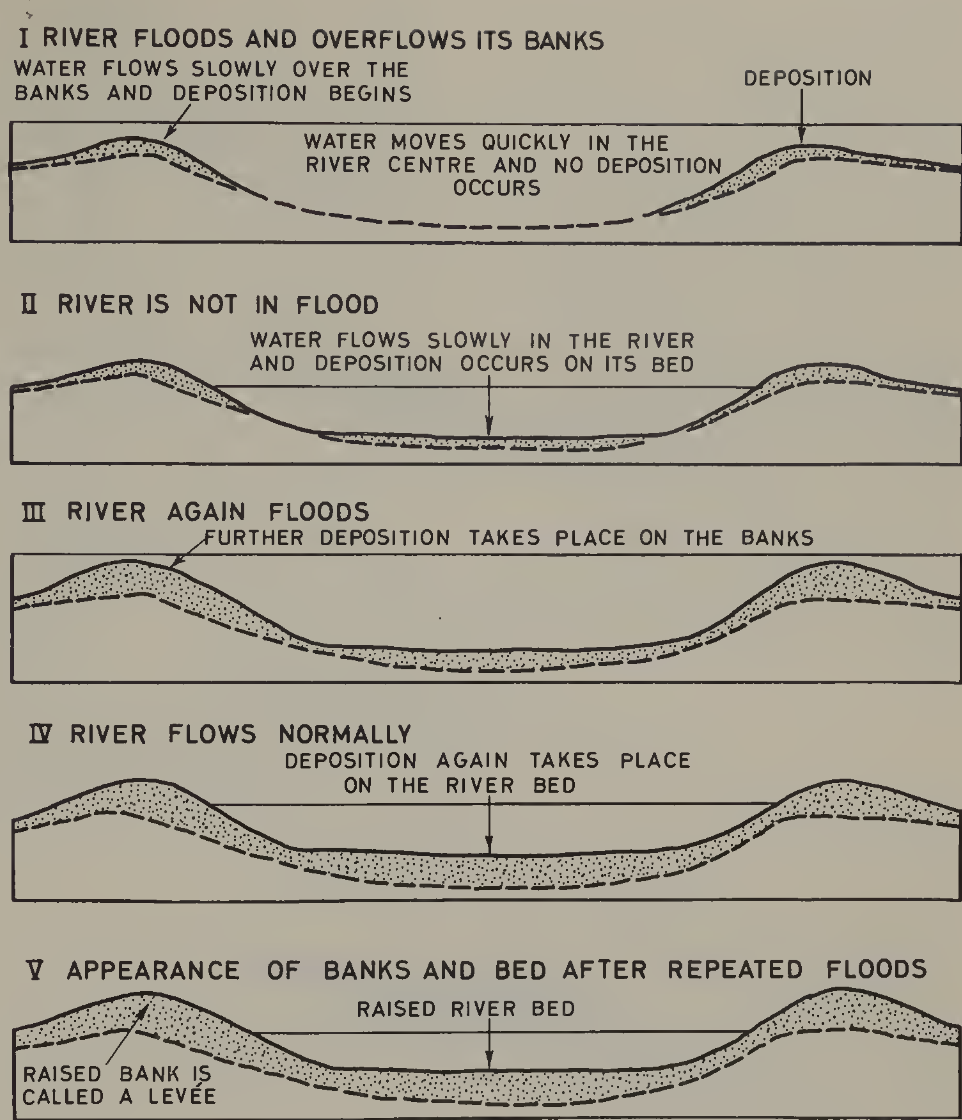
The photograph shows two pronounced meanders and an ox-bow lake (bottom left). The flood plain is clearly shown. Natural levees occur along both banks of the river. These are fairly conspicuous in the centre of the photograph.

The Formation of Levees and the Raising of the River Bed

1 Active deposition takes place along the banks of an old river when it is in flood. Each time this happens the banks get higher and they are called *natural levees*.

2 When the river is not in flood deposition takes place on the river's bed. The bed is thus raised.

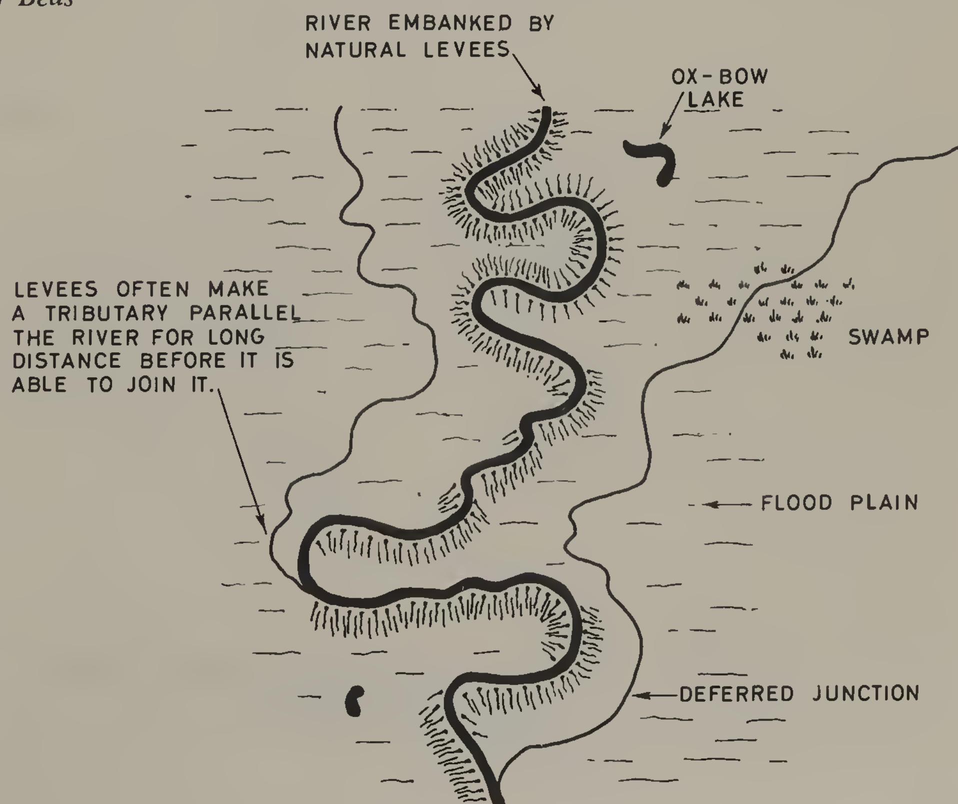
3 In time the river flows between levees and it is above the general level of the flood plain. The Hwang-ho and Yangtze-kiang in China; the Mississippi in the U.S.A. and the River Po in Italy all flow above the level of the flood plain in their lower courses.



The Influence of Levels and Raised River Beds

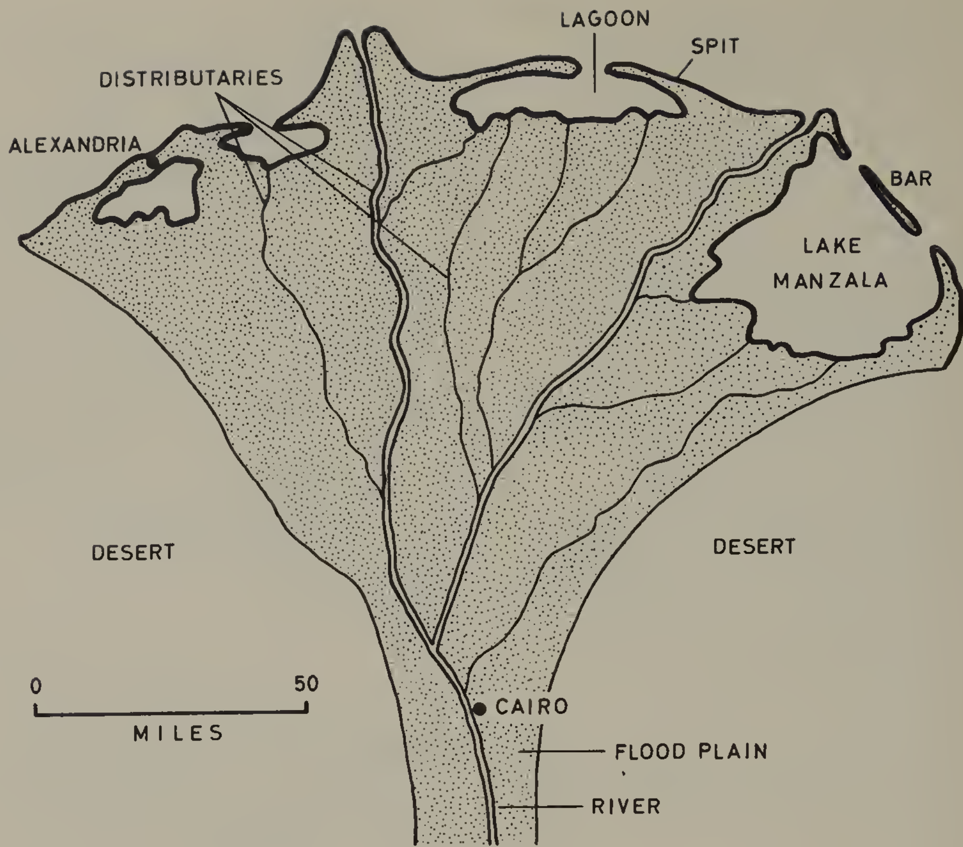
When a river flows above the level of its flood plain, its tributaries find difficulty in joining it. They often parallel the river for many miles and in doing so they frequently meander themselves. They may cross depressions in the flood plain which then become swampy. Tributaries whose confluence with the main river is interfered with in this way are called deferred junctions.

Rivers which flow above the level of their flood plains are a constant menace. In times of severe floods they sometimes burst through the levees and disastrous floods spread out over the flood plains. The Hwang-ho, Yangtze-kiang and Mississippi all flow above the level of their flood plains in their lower valleys, and all periodically produce disastrous floods.



Deltas

Most of the load carried by a river is ultimately dumped into the sea or lake into which it flows. The deposited load sometimes collects in the river mouth where it builds up into a low-lying swampy plain called a *delta*. As deposition goes on in the river mouth, the river is forced to divide into several channels each of which repeatedly divides. All these channels are called *distributaries*. Stretches of sea or lake become surrounded by deposited sediments and they form *lagoons* (lakes). In time these are filled in with sediments when they may persist for some time as swamps. *Spits* and *bars* develop along the front of the delta.



There are Three Basic Types of Delta

1 *Arcuate*

This type is very common. It is composed of coarse sediments such as gravel and sand and is triangular in shape (see diagram of Nile Delta). It always has a great number of distributaries. Rivers having this type of delta are: *Nile*, *Ganges*, *Indus*, *Irrawaddy*, *Mekong*, *Hwang-ho* and *Niger*.

2 *Bird's Foot Digitate*

This type is composed of very fine sediments such as silt. The river channel divides into a few distributaries only and these maintain clearly defined channels across the delta. The Mississippi Delta is one of the best examples of this type. The diagram on the right is of the *Vardar Delta*. Two main distributaries can be seen. Both of these are flowing between levees which is another characteristic feature of this type of delta.

3 *Estuarine*

An estuarine delta develops in the mouth of a submerged river. It takes the shape of the estuary. The deltas of the Elbe (Germany), Ob (U.S.S.R.) and the Vistula (Poland) are of this type.

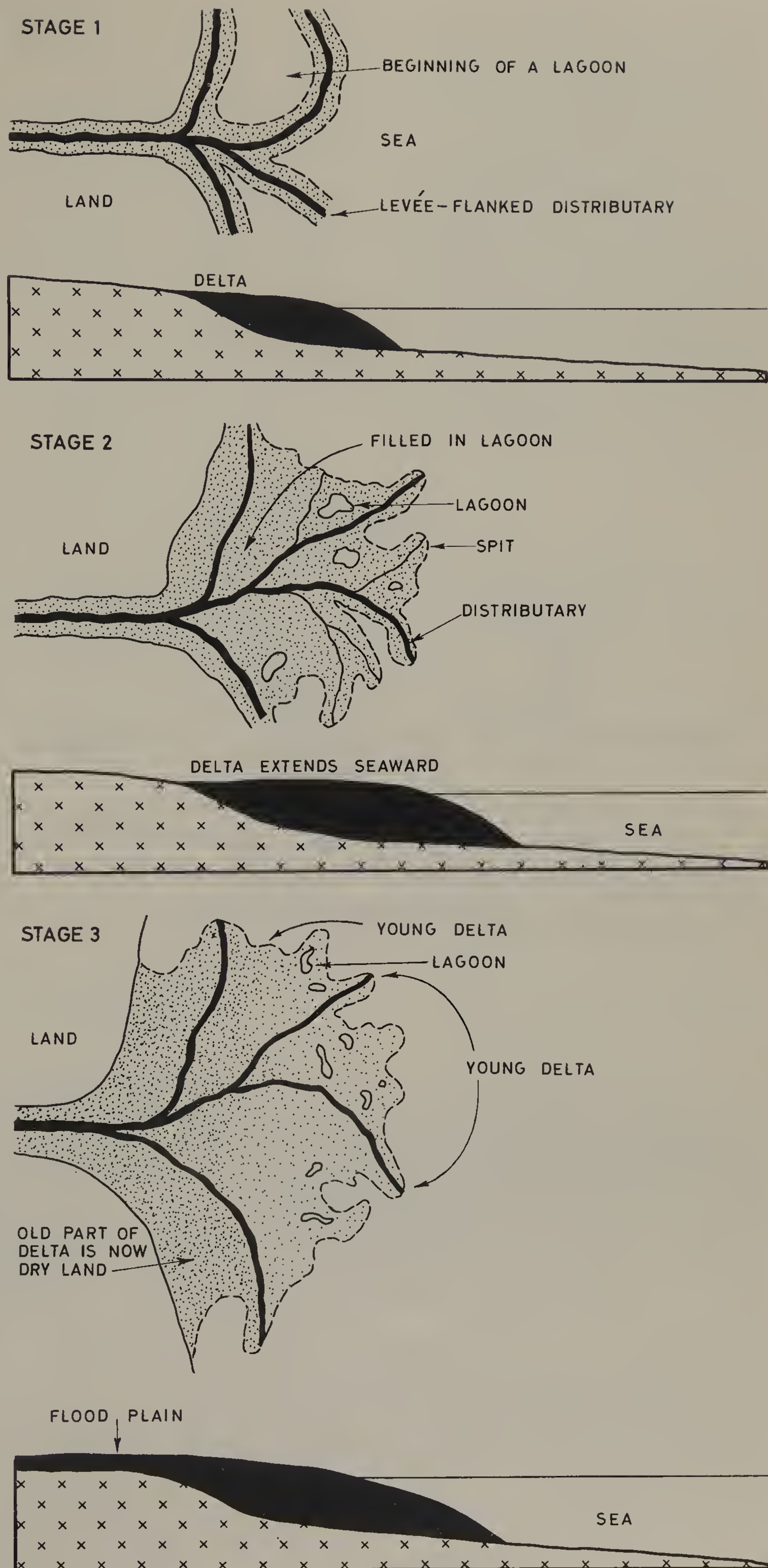
Stages in the Development of a Delta

In stage 1 deposition divides the river mouth into several distributaries. Spits and bars arise and lagoons are formed. The levees of the river extend into the sea via the distributaries.

In stage 2 the lagoons begin to get filled in with sediments, and they become swampy. The delta begins to assume a more solid appearance.

In stage 3 the old part of the delta becomes colonised by plants and its height is slowly raised as a result of this. Swamps gradually disappear and this part of the delta becomes dry land.

Note All three stages can often be seen in most deltas. As a delta grows larger and larger, the old parts merge imperceptibly with the flood plain, and they no longer have the appearance of a delta. Much of the North China Plain is the deltaic plain of the Hwang-ho; the plains of Iraq are the deltaic plains of the Tigris-Euphrates Rivers, and so on.



Conditions necessary for the Formation of a Delta

1 The river must have a large load, and this will happen if there is active erosion in the upper section of its valley.

2 The river's load must be deposited faster than it can be removed, by the action of currents and tides.

Note

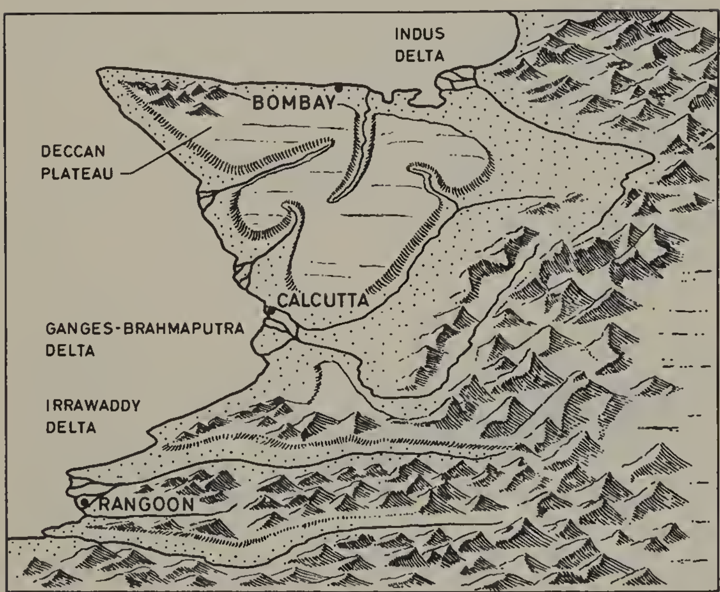
1 Deltas can, and do form on the shores of highly tidal seas, e.g. River Colorado (Gulf of California), and River Fraser (British Columbia).

2 Any river, irrespective of its stage of development, can build a delta. The Kander, whose valley is in the stage of youth, has built a delta in Lake Thun (Switzerland).

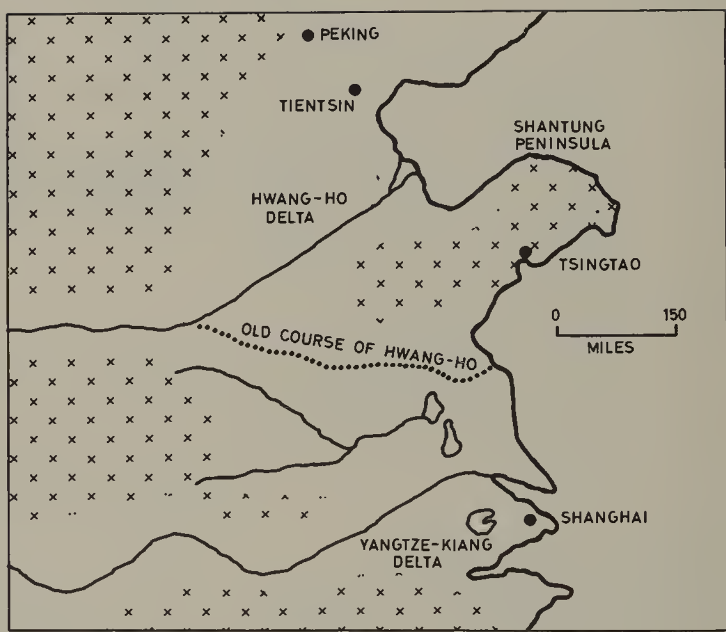
The Rate at which a Delta Grows

The formation of a delta results in an extension of the flood plain. Some deltas grow more rapidly than others. The Mississippi Delta is being extended seawards by 250 feet each year. The River Po (Italy) is extending its delta seawards by 40 feet per year. The advance of the Hwang-ho Delta has resulted in an island becoming joined to the mainland thus forming a peninsula (Shantung).

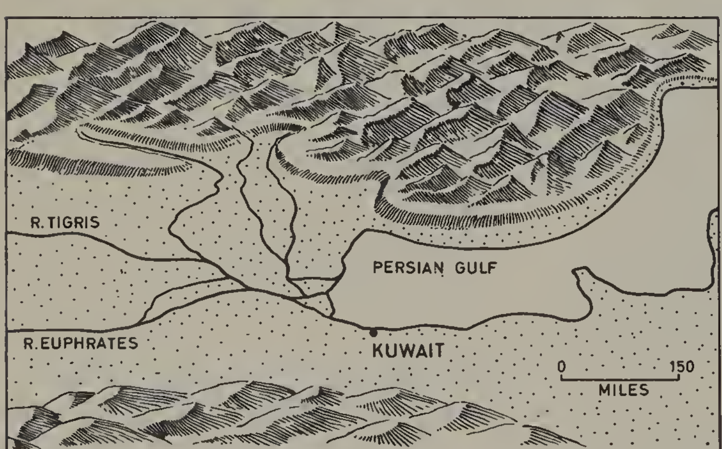
Some Common Deltas from Asia and Africa



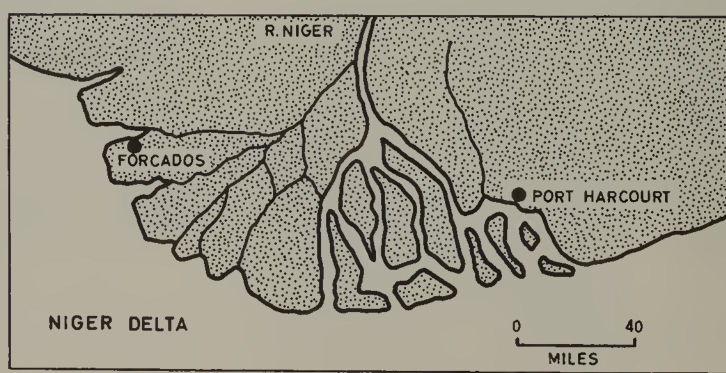
Deltas of India, Pakistan and Burma



Hwang-ho Delta



Tigris-Euphrates Delta



Niger Delta

The Value of Rivers and their Valleys to Man

Rivers

1. Some rivers, especially those in the stage of old age, form natural routeways which can be used for transport. The *Yangtze-kiang* and *Mississippi* and *Rhine* are particularly important.
2. Many rivers can be used for supplying irrigation water to agricultural regions, e.g. *Nile*, *Tigris-Euphrates*, *Indus* and *Yangtze-kiang* (irrigation will be discussed more fully in a later section).
3. For the development of hydro-electric power (H.E.P.). Young rivers which have waterfalls or which flow through gorges offer possibilities for H.E.P. development, e.g. of H.E.P. sites: *Kariba Dam* across the end of the gorge below the Victoria Falls on the *River Zambesi*; *Boulder Dam* near the Grand Canyon on the *River Colorado*; and *Owens Dam* near the Owens Falls on the *River Nile* where it leaves Lake Victoria. A dam is being built across the *Sanmen Gorge* on the *Hwang-ho*. Mature rivers can also be used for H.E.P. development, e.g. the dams at *Dnepropetrovsk* on the Dnieper, *Tsimlyanskaya* on the River Don, and at *Kuybyshev* on the River Volga all of which are in the U.S.S.R.
4. Some river mouths contain deep sheltered water and enablc ports to be developed there, e.g. *Calcutta* on a branch of the Ganges, *Alexandria* on a distributary of the Nile, *Shanghai* in the delta of the Yangtze-kiang and *New Orleans* in the Mississippi Delta.

Valleys

1. Young valleys extend into highland regions by headward erosion. In doing so they often develop gaps by river capture. These gaps together with river gaps offer fairly easy passageways across the highlands. Roads and railways often take advantage of these.
2. Mature valleys by virtue of their wider floors offer gently sloping routeways to roads and railways across highland areas.
3. Mature valleys also offer good sites for settlements. Bluffs and river cliffs are frequently used as settlement sites.
4. The flood plains and deltas of old valleys contain fertile soils and provide Man with some of the best agricultural land. This is especially true of the subtropics and humid tropics where flood plains and deltas have for long been the home of large populations. It was on the riverine plains of the *Nile*, *Tigris-Euphrates*, *Indus* and *Hwang-ho* that the early civilisations grew up. All of these except the Hwang-ho have remarkably similar physical environments:
   (i) each is bordered by mountains, or deserts, or both
   (ii) each is open to the sea on one side
   (iii) each has a mild winter, a hot summer and an abundance of river flood water.

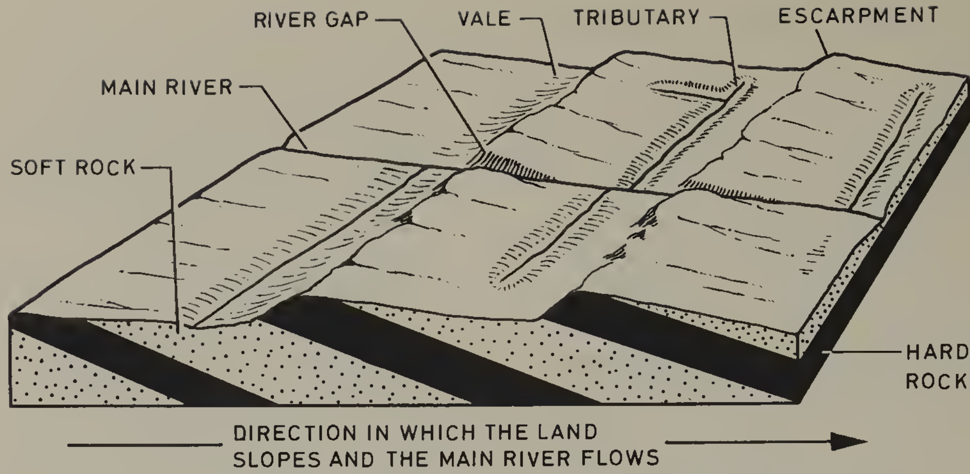
In Asia the flood plains and deltas form the most important physical landscapes, for most of the people live here. Wherever temperature and water conditions are suitable they are used for growing rice. The deltas of the *Yangtze-kiang* (China), *Red River* (Vietnam), *Mekong* (Vietnam), *Irrawaddy* (Burma) and the *Indus* (West Pakistan) are especially important rice-growing regions. Outside Asia the *Nile Delta*, the *Mississippi Delta* and the *Rhine Delta* are of great agricultural value.

Flood plains and deltas have their disadvantages. Sometimes their rivers cause serious flooding. This is particularly true when the river flows above the level of its flood plain and bursts its levees. Damage is done to crop land, settlements and communications. There may be considerable loss of life as there was in 1887 when the Hwang-ho burst its banks. Over 1,000,000 people lost their lives on the flood plain and delta in that year. The dangers of such serious flooding can be lessened by strengthening the levees and dredging the river to deepen its channel. The construction of dams across rivers also lessens the danger of flooding, e.g. as in the Nile Valley.

Drainage Patterns

All rivers are joined by smaller rivers or streams which are called *tributaries.* The area drained by a river and its tributaries is known as a *river basin* and its boundary is formed by the crest line of the surrounding highland. This boundary forms the main *watershed* of the basin. There are two types of drainage pattern:

(i) Dendritic
(ii) Trellis



THE MAIN RIVER CUTS THROUGH THE HARD ROCK FORMING THE ESCARPMENT AND A RIVER GAP IS PRODUCED

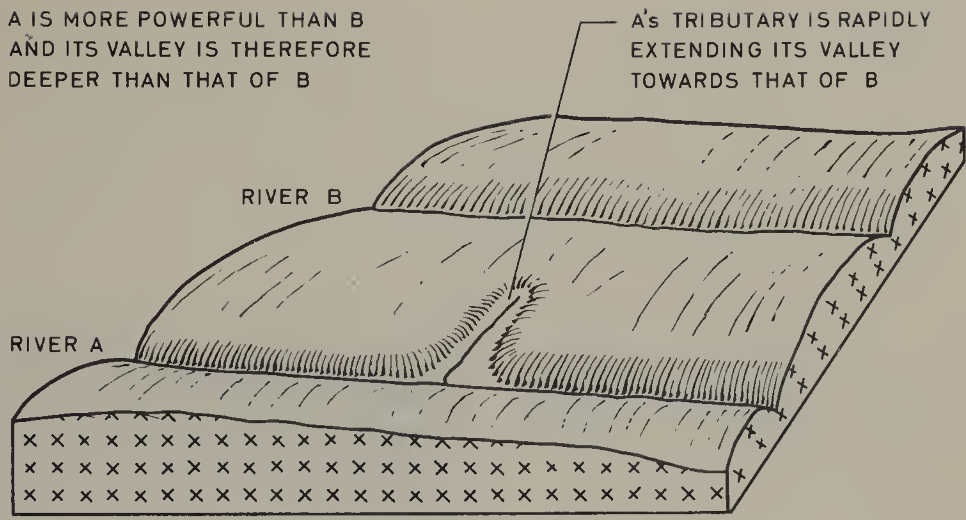
The trellis pattern develops in a region which is made up of alternate belts of hard and soft rocks which all dip in the same direction. The tributaries of the main river extend their valleys by headward erosion into the weak rocks which are turned into wide valleys. The hard rocks stand up as *escarpments.*

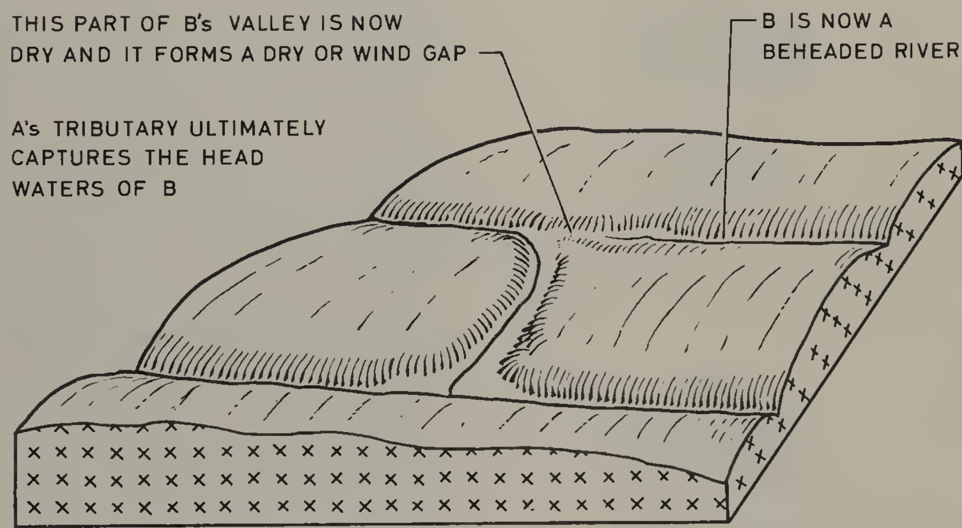
Macdonnell Range Watershed in Northern Australia

A dendritic drainage pattern develops in a region which is made of rocks which offer the same resistance to erosion. The directions of rivers and their tributaries are determined by slope. The land between main valleys and between these and tributary valleys stands up as *ridges* and *spurs.* The crests of these are watersheds.

Colorado River Delta

River Capture and Dry Gaps
The diagrams show how river capture can take place. After A's tributary captures the headwaters of B, the beheaded part of this river dwindles in size and is too small for its valley. It is called a *misfit*.





Wind Action and the Features it Produces

Wind action is very powerful in arid and semi-arid regions where rock waste is produced by weathering and is easily picked up by the wind.
In humid regions rock particles are bound together by water droplets and hence there is little wind erosion.

Wind erosion consists of *abrasion* which breaks up rocks and produces rock pedestals, zeugens, yardangs and inselbergs, and *deflation* which blows away rock waste and thus lowers the desert surface producing depressions, some of which are very extensive.

Wind transport causes fine particles of rock waste, called desert dust, to be carried great distances. Coarser particles called sand are bounced over the surface for short distances.

Wind deposition gives rise to dunes which are made of sand and loess which is made of desert dust.

Types of Desert Surface

Sandy Desert—called erg in the Sahara and koum in Turkestan. This is an undulating plain of sand produced by wind deposition.

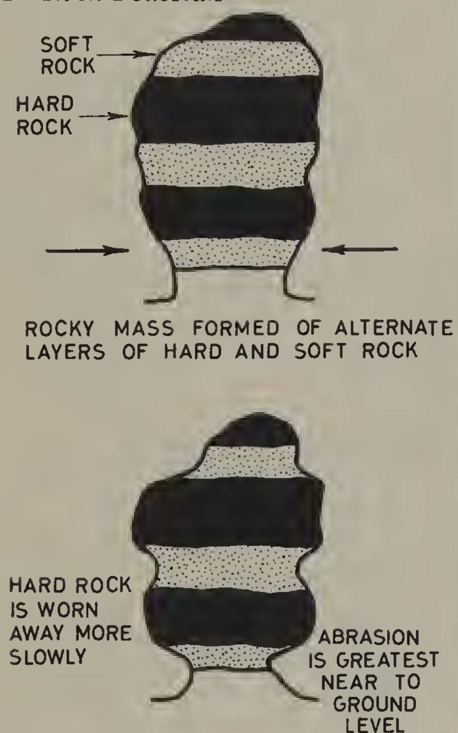
Stony Desert—called serir in Libya and Egypt and reg in Algeria. This desert surface is covered with boulders and stones produced by temperature changes.

Rocky Desert—called hamada in the Sahara. The bare rock surface of this desert is formed by deflation which removes all the loose rock particles.

Features Produced by Wind Erosion

Wind abrasion attacks rock masses and sculptures them into fantastic shapes. Some of these because of their shape are called rock pedestals.

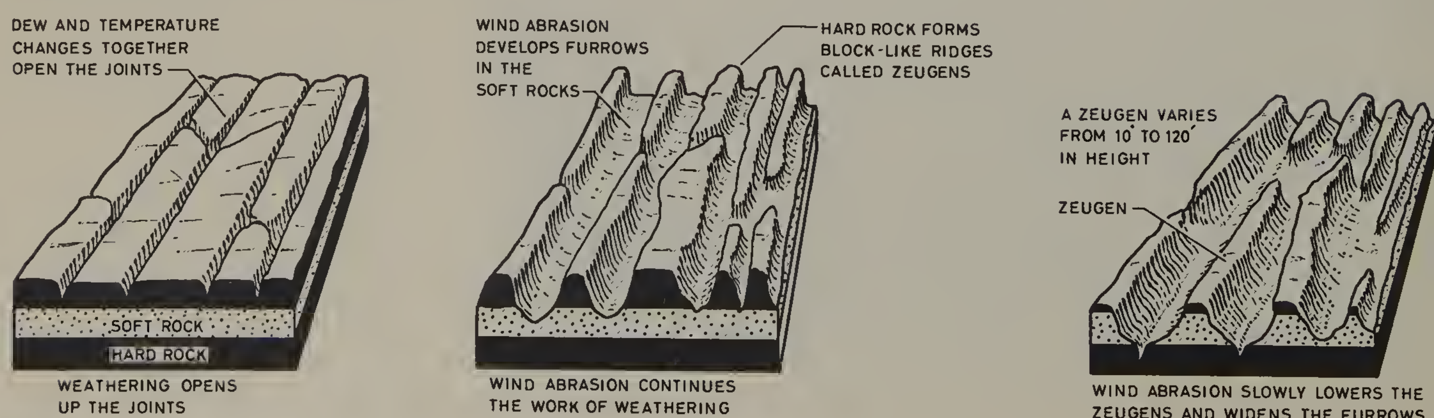
I *Rock Pedestals*



Rock Pedestals in the Lut Desert in Persia

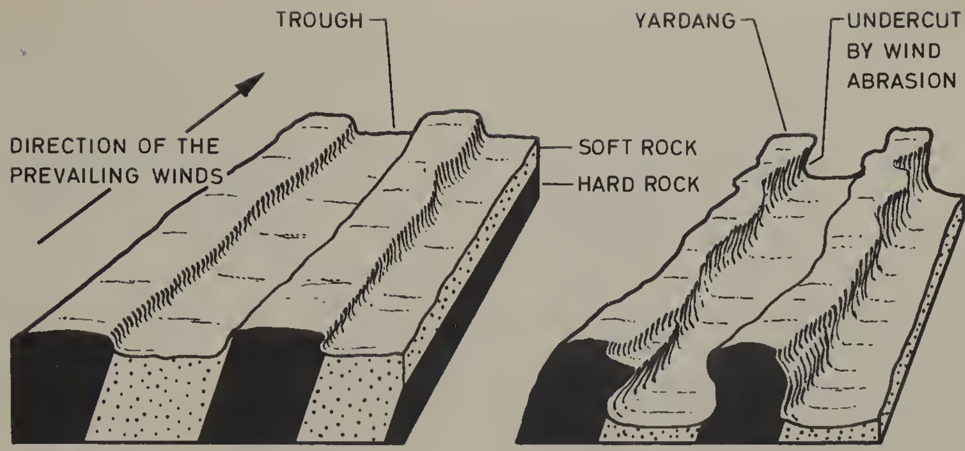
II *Zeugens*

Wind abrasion turns a desert area which has a surface layer of hard rock underlain by a layer of soft rock into a 'ridge and furrow' landscape. The ridges are called *zeugens*. A zeugen may be as high as 100′. Ultimately they are undercut and gradually worn away.



III *Yardangs*

Bands of hard and soft rocks which lie parallel to the prevailing winds in a desert region are turned into another type of 'ridge and furrow' landscape by wind and abrasion. The belts of hard rock stand up as rocky ribs up to 50′ in height and they are of fantastic shapes. They are called *yardangs*. Yardangs are very common in the Central Asian deserts and in the Atacama Desert.

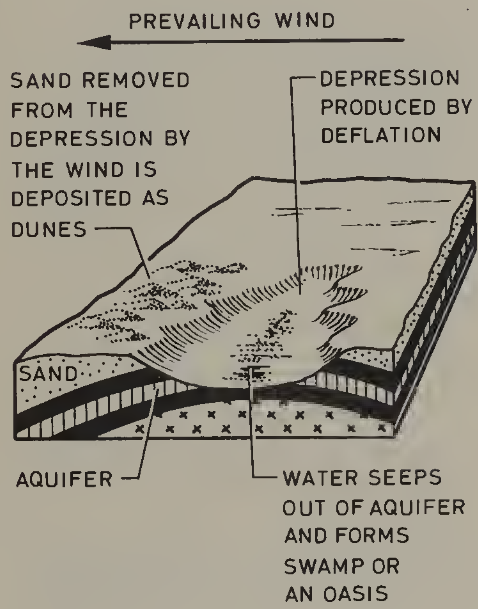


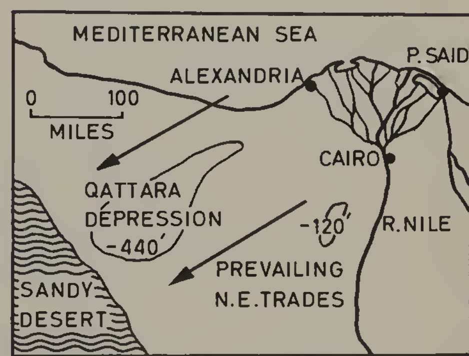
WIND ABRASION TURNS THE BELTS OF SOFT ROCKS INTO TROUGHS

HARD ROCKS ARE UNDERCUT AND THEY STAND UP AS NARROW RIDGES CALLED YARDANGS

IV *Depressions*

Some depressions produced by wind deflation reach down to water-bearing rocks. A swamp or an oasis then develops.



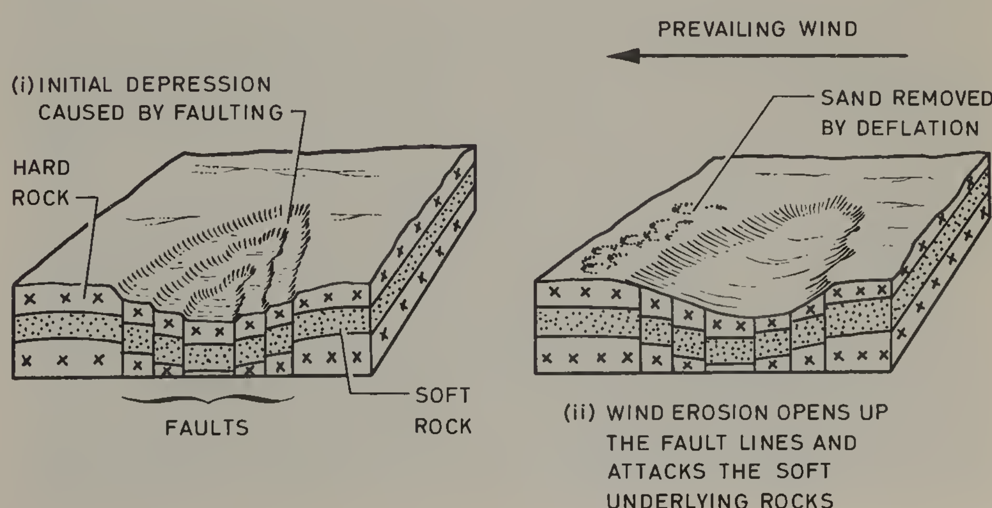


Qattara Depression in Egypt

The Qattara Depression is 400′ below sea level. It has salt marshes and the sand excavated from it forms a zone of dunes on the lee-side.

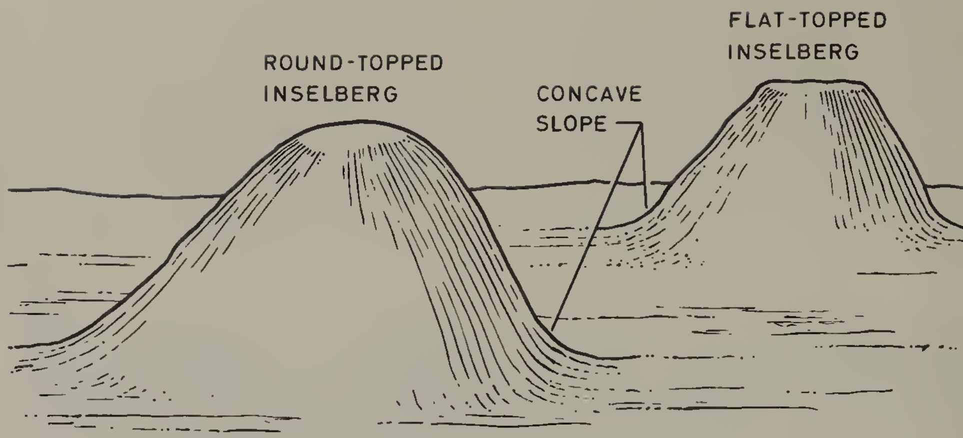
Fault-produced depression

The formation of a depression may first be caused by faulting. The soft rocks thus exposed are excavated by wind action.



V Inselberg

After a long time depressions merge with one another. All that remains of the original desert surface are pillar-like rocky masses whose tops are rounded and slopes are steep. These are called inselbergs. They may be the result of wind erosion or the combined action of wind erosion and water erosion. Inselbergs are common in the Kalahari Desert, parts of Algeria and in North Western Nigeria.



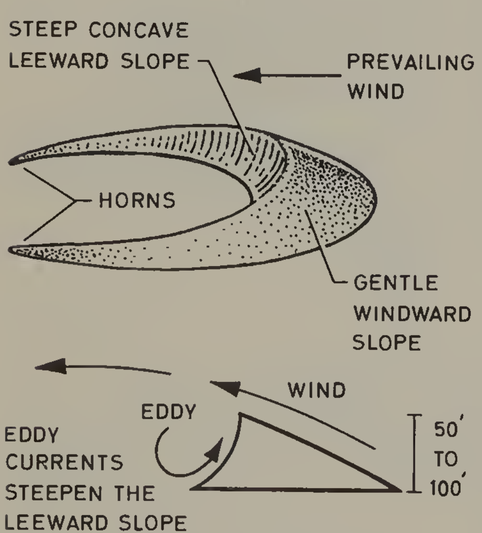
Features Produced by Wind Deposition

Sand Dunes

Sand collects around obstacles such as rock or bits of vegetation and forms little hills of sand called dunes. If these are moon-shaped they are called barchans, and such dunes are common in the deserts of Asia and Africa.

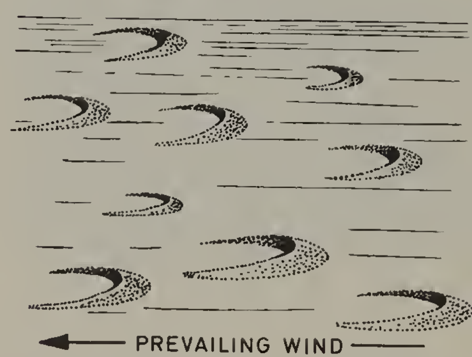
Barchans can occur singly or in groups. Cross winds sometimes break up barchans into ridge-type dunes which are called seifs. These are usually several hundred feet high and many miles long. Seifs occur to the south of the Qattara Depression, in the Thar Desert and the desert of Western Australia.

BARCHAN (BARCHANE OR BARKHAN)



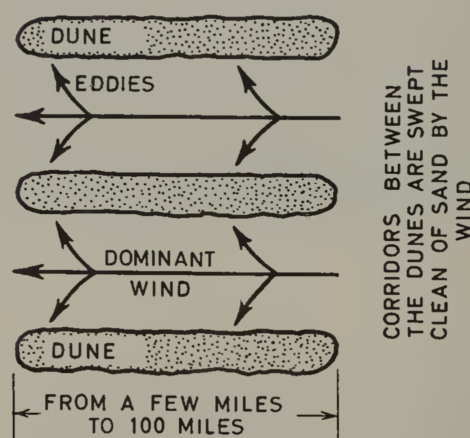
CROSS SECTION OF A BARCHAN

A GROUP OF BARCHANS



BARCHANS SLOWLY ADVANCE AT THE RATE OF A FEW FEET PER YEAR IN THE DIRECTION OF THE PREVAILING WINDS

SAND RIDGES OR SEIF DUNES



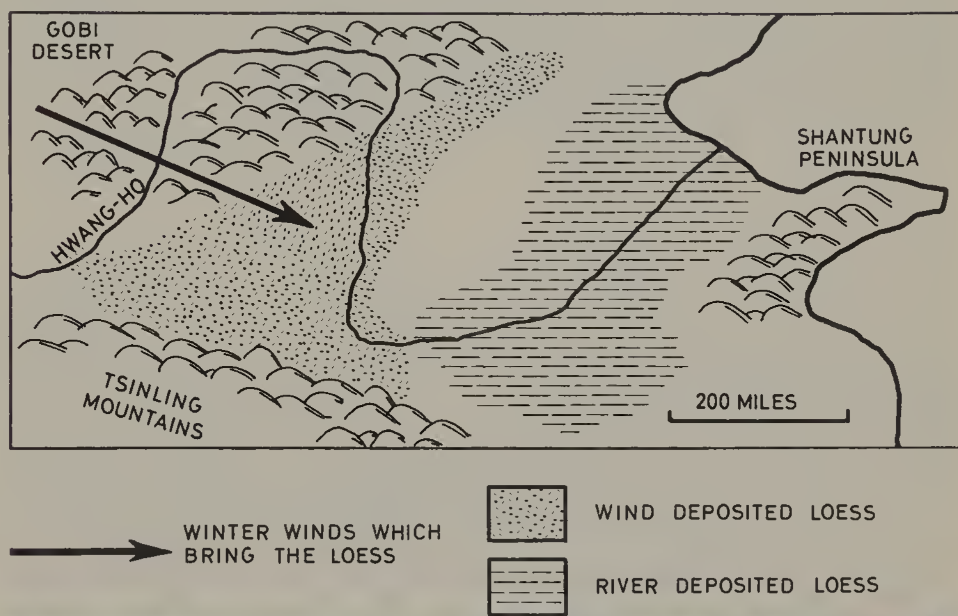
A SEIF DUNE IS USUALLY A FEW HUNDRED FEET HIGH

Loess Deposits

The wind blows fine particles out of the deserts each year. Some are blown into the sea, the rest are deposited on the land where they accumulate to form loess. Loess is friable and easily eroded by rivers. There are extensive loess deposits in Northern China. These are formed of desert dust blown out of the Gobi Desert to the west. The loess deposits of Central Europe were probably deposited in the last Ice Age when out-blowing winds carried fine glacial dust from the ice-sheets of Northern Europe. The loess deposits of the Pampas have been derived from the deserts to the west.

LOESS REGIONS OF THE WORLD

LOESS REGION OF NORTHERN CHINA



In Northern China the loess has been intensely eroded by rivers to to give a 'badland' landscape. The photograph on the right shows deep gorge-like valleys which have been cut into the loess. The centre of the photograph shows a loess plain which is under cultivation.
Many of the loess hills are terraced for crops. Most of the people in this loess region live in houses which have been carved out of the loess cliffs.

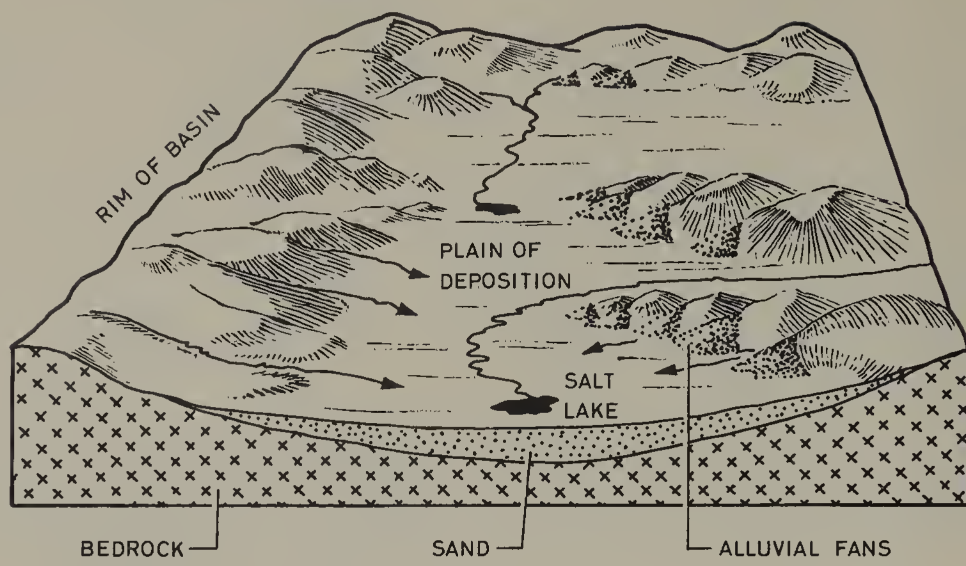
Loess deposits in Shensi Province of China. Erosion has turned this into a 'badland'

Water also takes a hand in Sculpturing a Desert Landscape

A desert region may receive no rain for several years and then a sudden downpour of from 5″ to 10″ occurs. These rare but heavy rain storms give birth to rushing torrents which, though only short-lived, produce great changes in the desert landscape. The torrents which carry large quantities of sediment soon dry up as their water seeps into the ground. Their loads are deposited in bulk giving rise to alluvial fans and delta-like deposits. In plateau regions the deposits occur around the edges of the plateau and at the exits of the wadis.

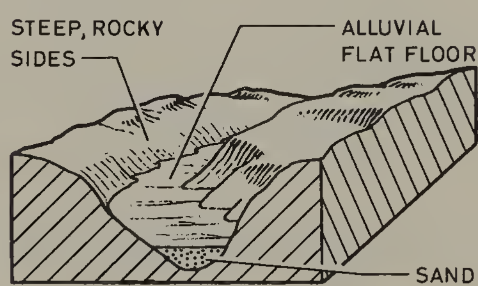
In intermontane basin deserts, e.g. *Tarim Basin*, intermittent rivers drain into the centre of the basins. The deposits around the edges of the basins build up a gently sloping alluvial plain called a *piedmont*. Sometimes the centres of the basins are occupied by salt lakes, e.g. the *shotts* of North Africa and *bolsons* and *playas* of North America. Most desert highlands have steep-sided and flat-floored valleys which only rarely contain rivers. These valleys are called *wadis* (chebka in Algeria). Water erosion becomes more pronounced in semi-arid regions which then become heavily dissected by wadi-like gorges. Such a landscape is known as a *badland*. Badlands are common in the semi-arid South West of North America (see also the badlands of the loess region of North China)

OCCASIONAL RAINFALL GIVES RISE TO INTERMITTENT RIVERS



Intermontane Desert Basin

WADI

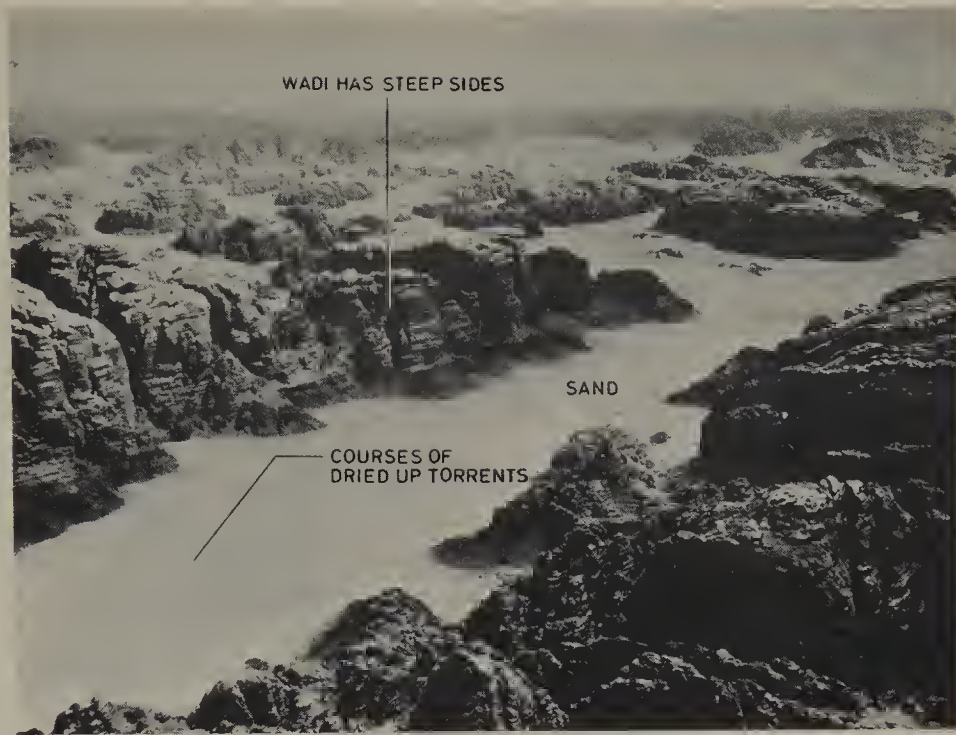


Crescent Dunes in North Africa

Deserts and Rivers

1 Most deserts are regions of *inland drainage*, i.e. streams and rivers never reach the sea.

2 Very few rivers persist throughout the year in desert regions. The *Nile* in North Africa, the *Tigris-Euphrates* in South West Asia and the *Colorado* in U.S.A. are the three best examples of rivers which cross desert areas and which are permanent rivers.



Wadis and Rocky Ridges in Jordan

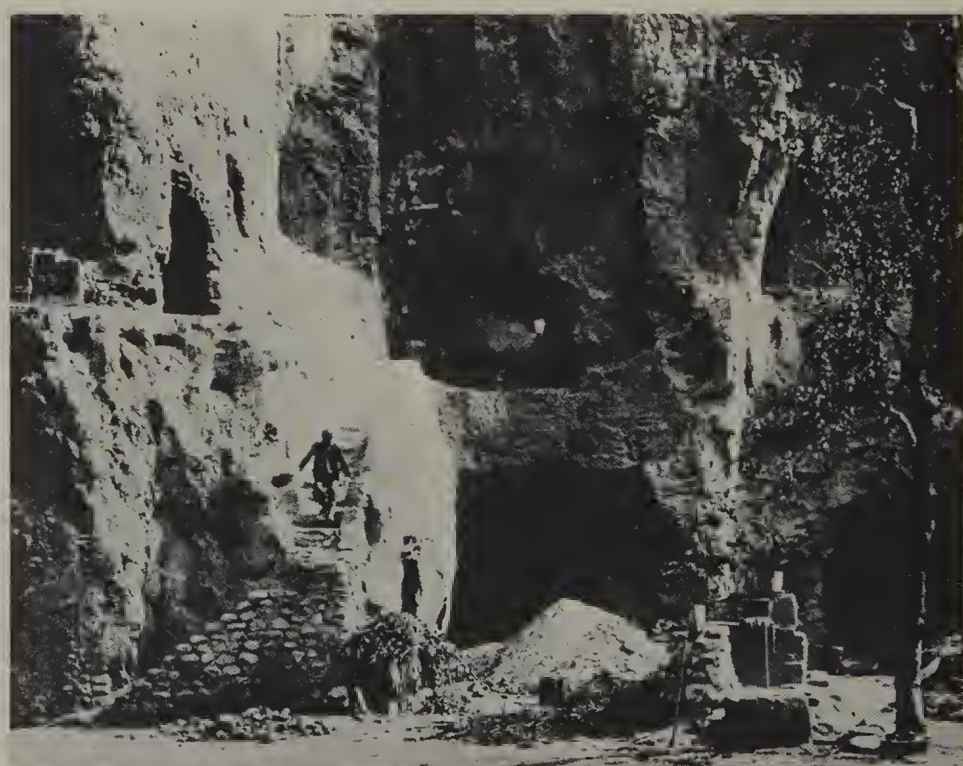
Mount Sinai in Egypt

Reg of Sinai

The Values of Wind-blown Deposits to Man

1 *Loess deposits* are unusually fertile. In *Northern China* the loess region has been cultivated for 4,000 years. In the *Ukraine* (north of the Black Sea), in the *Pampas* of Argentina, and in the *High Plains* of the U.S.A., the loess soils are very fertile and are used for grain growing.
2 Loess deposits of both China and Europe are used as a means for building dwellings. These are cut into the deposits. Their chief advantages are the ease with which they are built and their warmness in winter and their coolness in the summer. Their main disadvantage is their instability (they often collapse during even mild earthquakes).

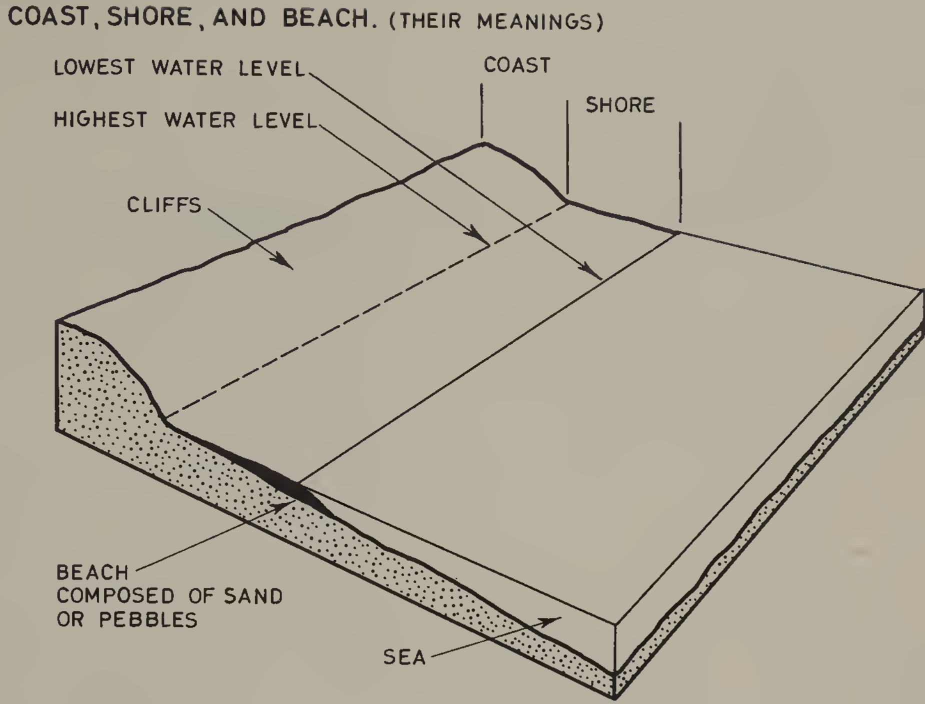
This map shows those deserts where wind action is important



Loess cave dwellers of Shansi Province in Northern China. These cave dwellers are warm in winter and cool in summer; however just slight earthquakes can cause serious landslides and the consequent loss of many lives

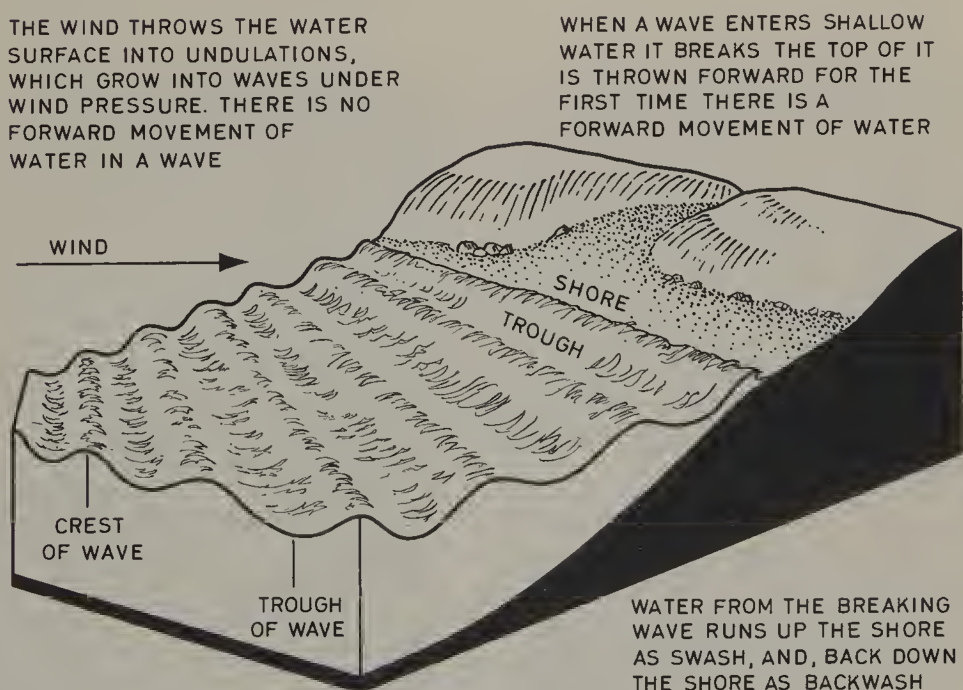
Sea Action and the Features it Produces

Coasts are forever changing—some are retreating under wave erosion and others are advancing under wave deposition. There are many different types of coasts; some are steep, some are gentle, some are sandy, some are rocky. The character of a coast results from two or more of the following factors:
1 Wave action; 2 Nature of the rocks forming the coast; 3 Slope of the coast; 4 Changes in the level of sea or land; 5 Volcanic activity; 6 Coral formations; and 7 The effects of glaciers.



Definition of Terms

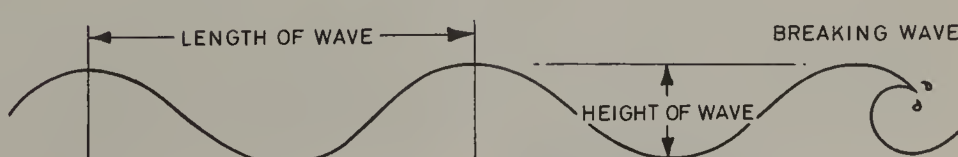
Find out the meanings of *coast*, *shore* and *beach* by studying the diagram on the right. The highest water level refers to the level reached by the most powerful storm waves. The lowest water level refers to the level of the lowest tide. The coastline is the margin of the land. This is also the cliff line on rocky coasts. The height and power of a wave depend upon the strength of the wind and the *fetch* (distance of open water over which it blows). The stronger the wind and the greater the fetch, the more powerful the wave. Storm waves are particularly powerful.



Waves as Agents of Erosion

Wave erosion consists of three parts:

1 *Corrasive action:* boulders, pebbles and sand are hurled against the base of a cliff by breaking waves and this causes undercutting and rock break-up.
2 *Hydraulic action:* Water thrown against a cliff face by breaking waves causes air in cracks and crevices to become suddenly compressed. When the wave retreats the air expands; often explosively. This action causes the rocks to shatter as the cracks become enlarged and extended.
3 *Attrition:* Boulders and pebbles dashed against the shore are themselves broken into finer and finer particles.



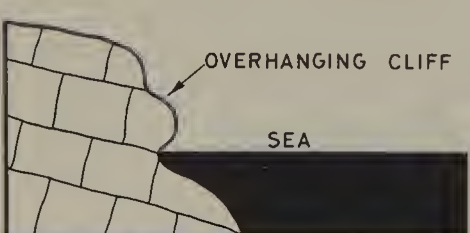
Features Produced by Wave Erosion

Cliffs and Wave-cut Platforms

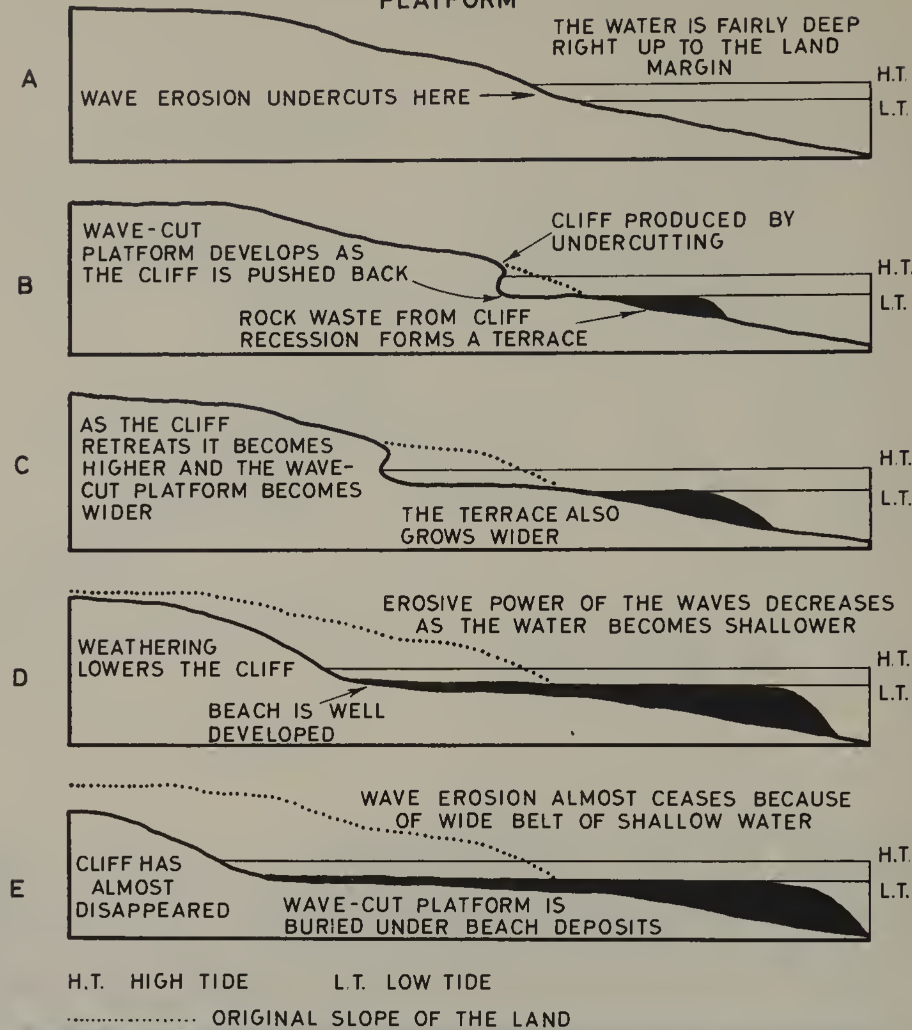
The *Strandflat* off the west coast of Norway is a good example of a wave-cut platform. This platform is over 30 miles wide.

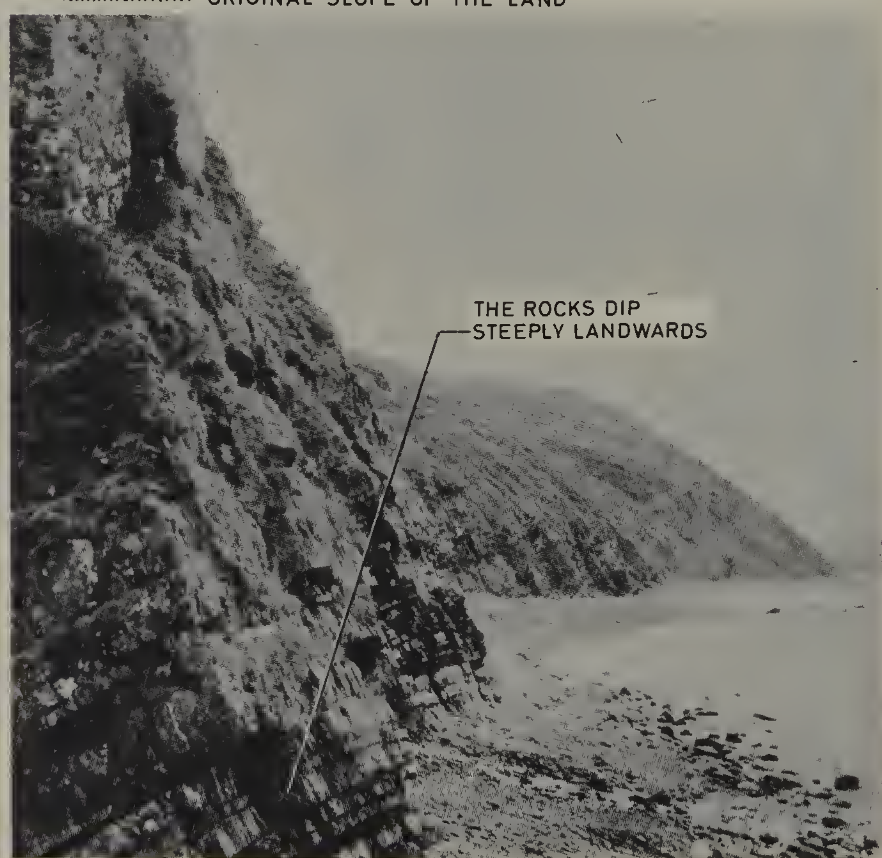
Types of Cliffs

The rocks of some cliffs are in layers which slope landwards (fig. A) In other cliffs the rock layers slope seawards and blocks of rock loosened by erosion easily fall into the sea. These cliffs are often very steep and overhanging (fig. B). Landslides are quite common on cliffs more especially on those formed of alternate layers of pervious and impervious rocks.



STAGES IN THE DEVELOPMENT OF A CLIFF AND WAVE-CUT PLATFORM

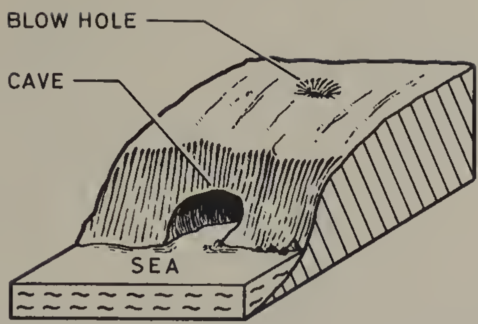


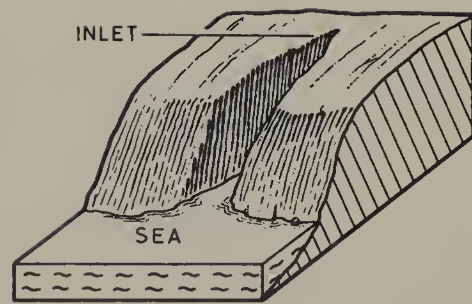


Part of the Devon Coast of S.W. England

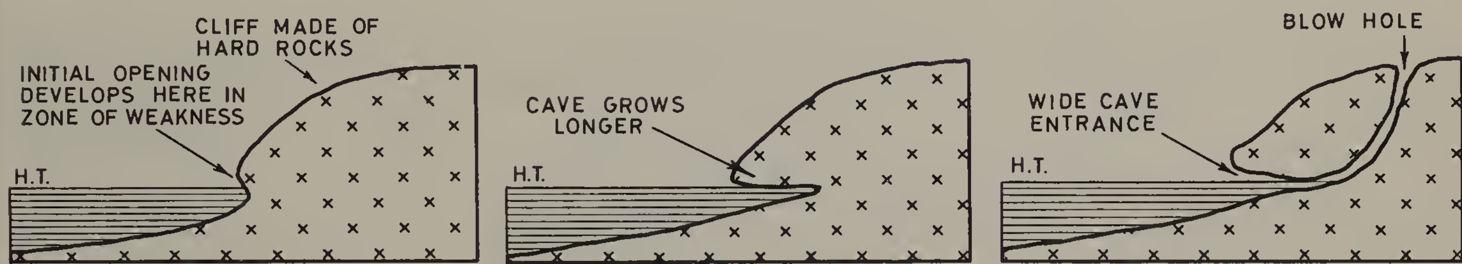
Caves, Arches and Stacks

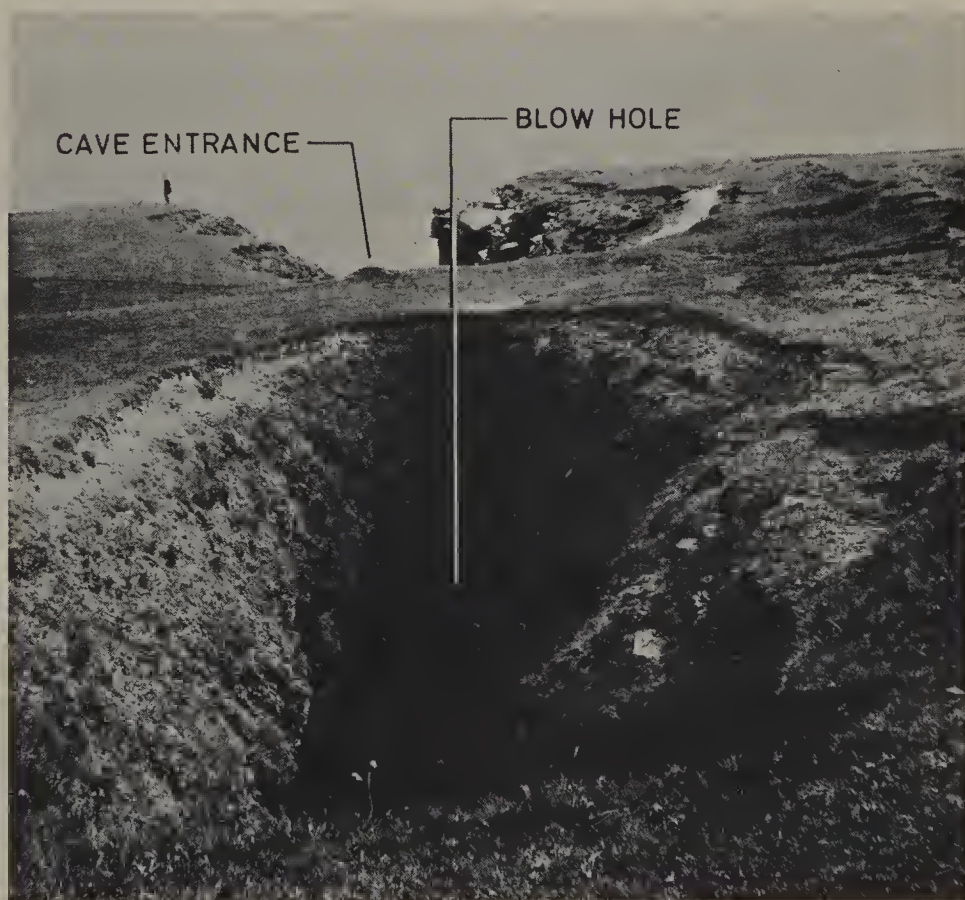
These are minor features produced by wave action during the process of cliff formation. A cave develops along a line of weakness at the base of a cliff which has been subjected to prolonged wave action. It is a cylindrical tunnel which extends into the cliff, follwing the line of weakness, and whose diameter decreases from the entrance. If a joint extends from the end of the tunnel to the top of the cliff, this becomes enlarged in time and finally opens out on the cliff top to form a *blow hole*. The roof of the cave ultimately collapses and a long narrow sea inlet forms.





ROOF OF CAVE HAS COLLAPSED AND A NARROW INLET IS FORMED



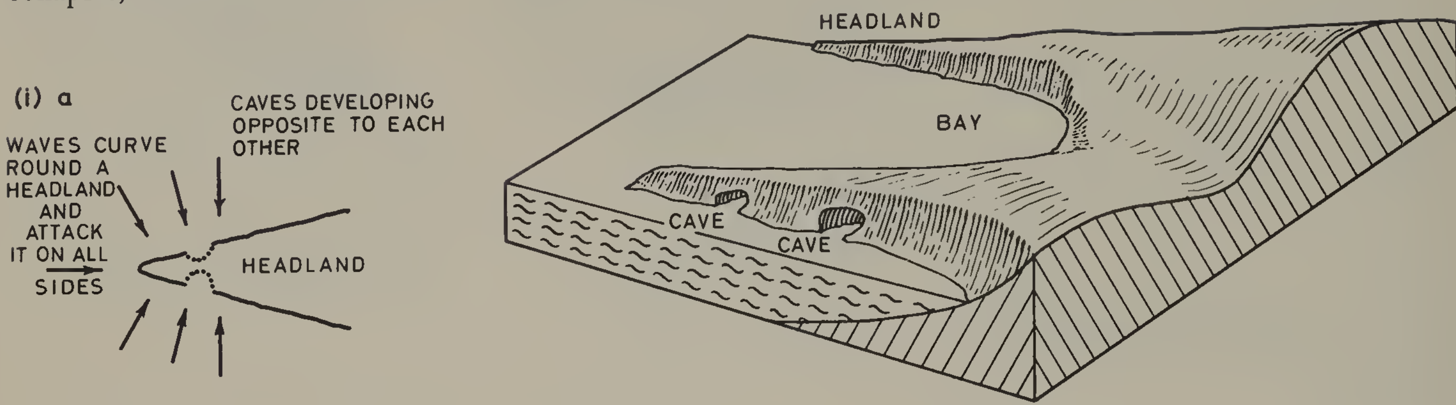


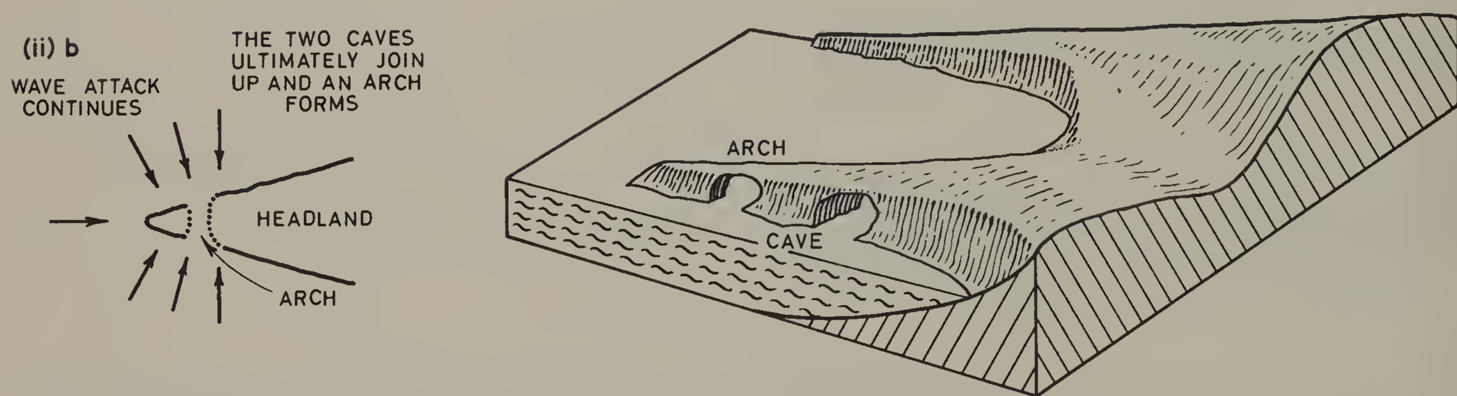
A Blow Hole in Scotland

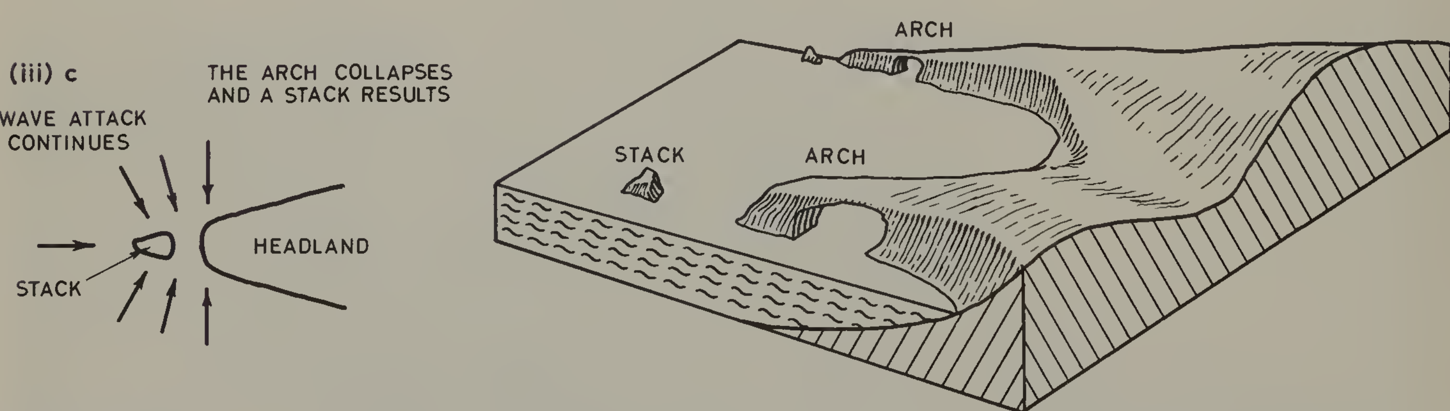
Stacks and Arches

Caves which develop on either side of a headland such that they ultimately join together, give rise to a natural *arch*. When the arch collapses, the end of the headland stands up as a *stack*. In time this is completely removed by wave erosion.

The diagrams below show the stages in the development of an arch and a stack.







Wave Transport

All the material carried by breaking waves is called the *load*. Some of this comes from rivers entering the sea, some from landslides on cliffs, and the rest comes from wave erosion. The load consists of mud, sand and shingle.

Water thrown up the beach by breaking waves is called the swash. When this runs back into the sea it is called the backwash. The swash and backwash push and drag material up and down the beach. When waves break obliquely to the shore the swash moves obliquely up the beach but the backwash runs back at right angles to the shore as shown in *fig. c* on page 79. You will see from this diagram that material is gradually carried along the beach by these two actions which together constitute longshore drift. The removal of material by longshore drift can be stopped by building groynes or walls out to sea (*fig. b*, page 79). Material is also carried off-shore into deeper water by the undertow. This is an under current which balances the piling up of water along the coast by breaking waves and high tides.

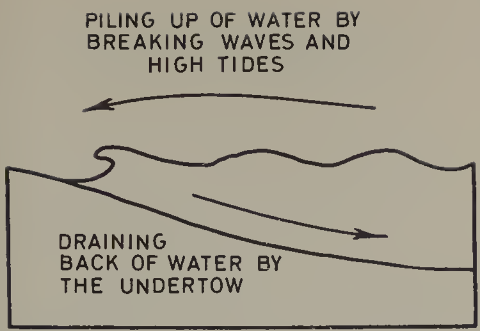


Fig. a

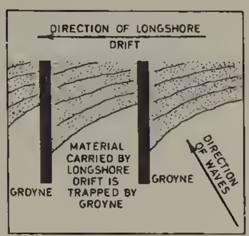


Fig. b

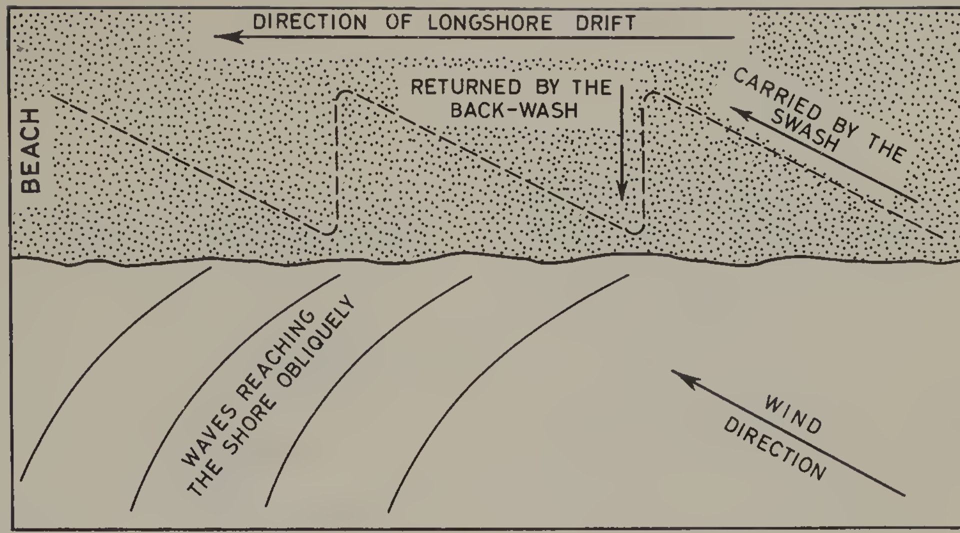


Fig. c

Erosion is Dominant on a Highland Coast

Examine *fig. d.* The only depositional feature is a narrow beach.

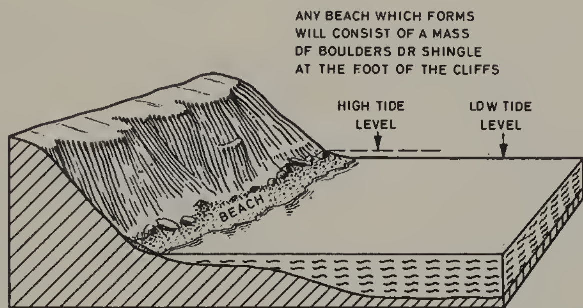


Fig. d

Deposition is Dominant on a Lowland Coast

Examine *fig. e* and compare it with *fig. d.* Along the highland coast there is deep water close to the land.

The photograph shows that the sea like the wind and rivers sorts its. load on deposition. Moving down the beach the sequence of deposits is boulders, pebbles, sand and mud. The coast is gently sloping. This is shown by the wide expanse of beach.

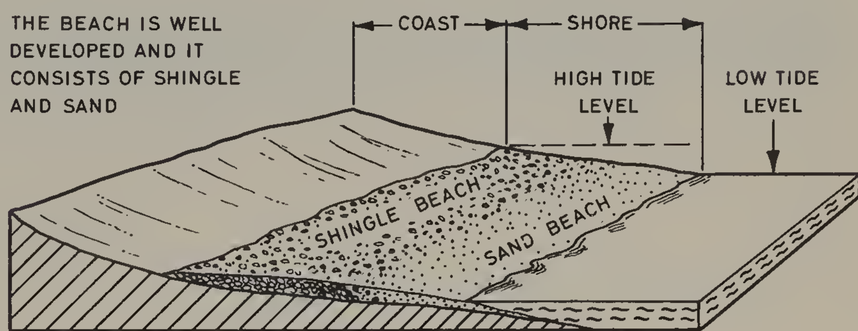
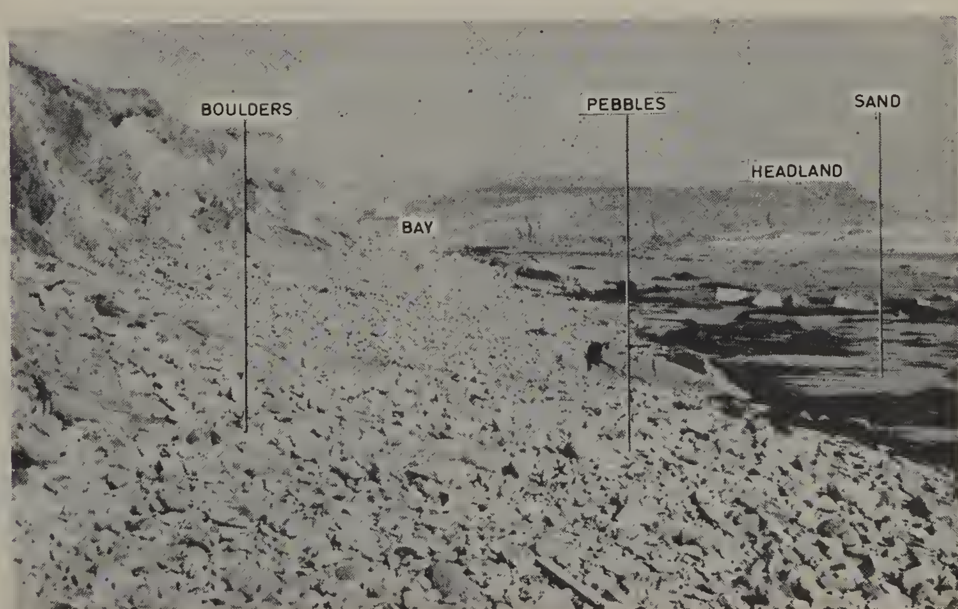


Fig. e



Wave-deposited material on the Devon Coast, England

Wave Depositional Features

The chief of these are:

(i) Beaches
(ii) Spits and bars
(iii) Salt-marshes and mud-flats.

Beach: It lies between high and low water levels and may be made of pebbles, or sand or both. Bay beaches develop at the heads of bays as shown in *fig. f*

Spit and bar: These arise along indented coasts where longshore drift operates. A spit is a low-lying, narrow ridge of sand or pebbles joined to the land at one end and terminating in deep water. It may form across a bay (*fig. h*), or across a river mouth (*fig. g*). Spits are very common along the front of a delta (diagram top of page 62). Waves bend when they enter a bay and thus bay spits are curved.

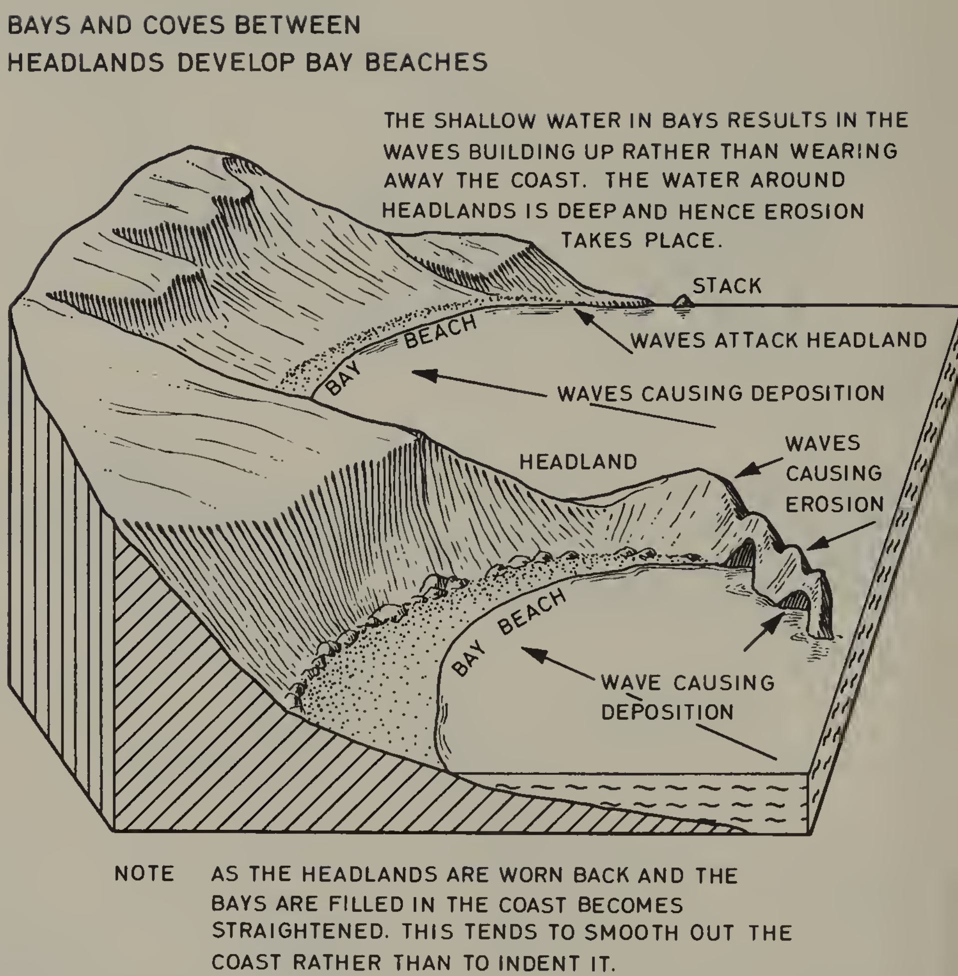


Fig. f

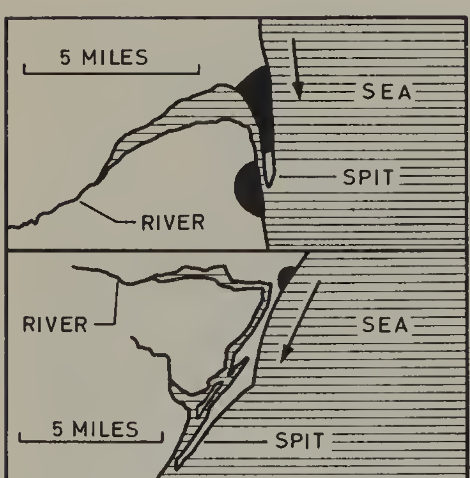


Fig. g

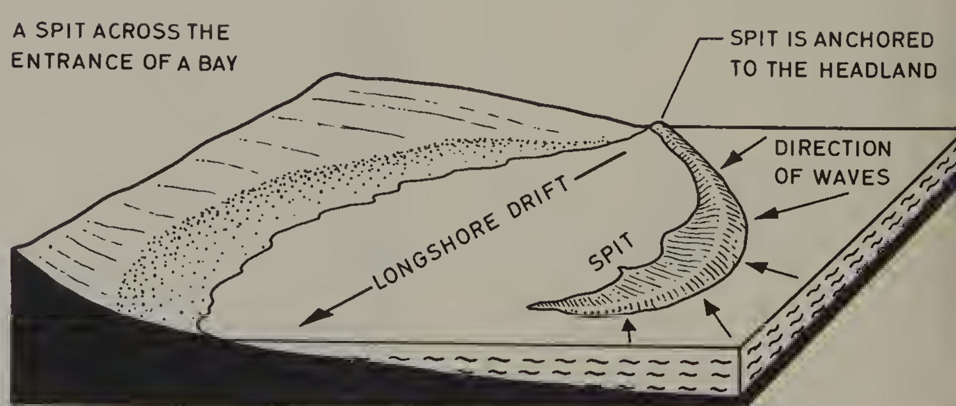
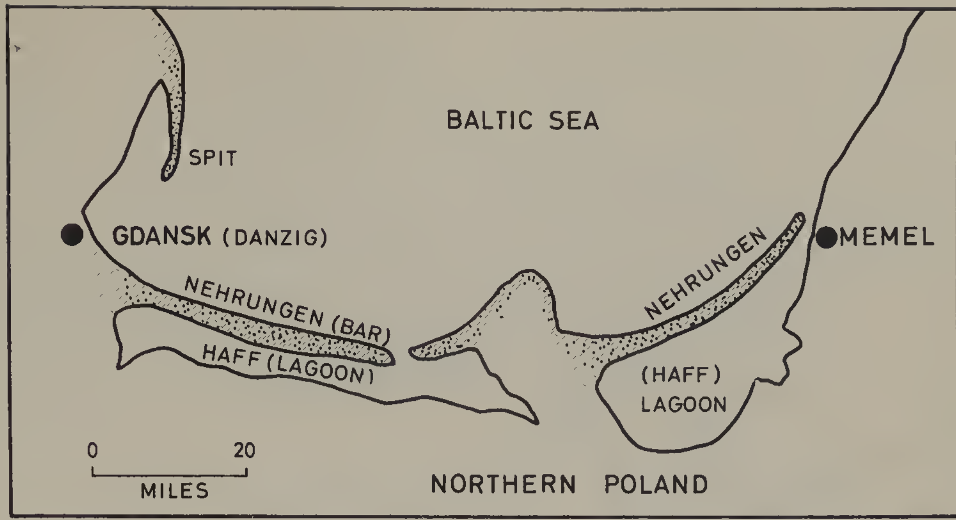


Fig. h

A *bar* is very similar to a spit. A common type of bar is that which extends right across a bay. This starts as a spit growing out from one of the headlands, but ultimately it stretches across the bay to the opposite headland. Many bay bars have a break in them where tidal action prevents the bar from being continuous. Along the coast of Poland bay bars are called nehrungs. Chesil Beach along the coast of South West England is a particularly good example of a bar.

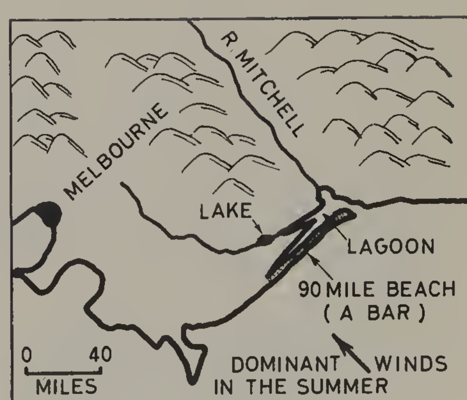


Chesil Beach in S.W. England

Examples of some Bars

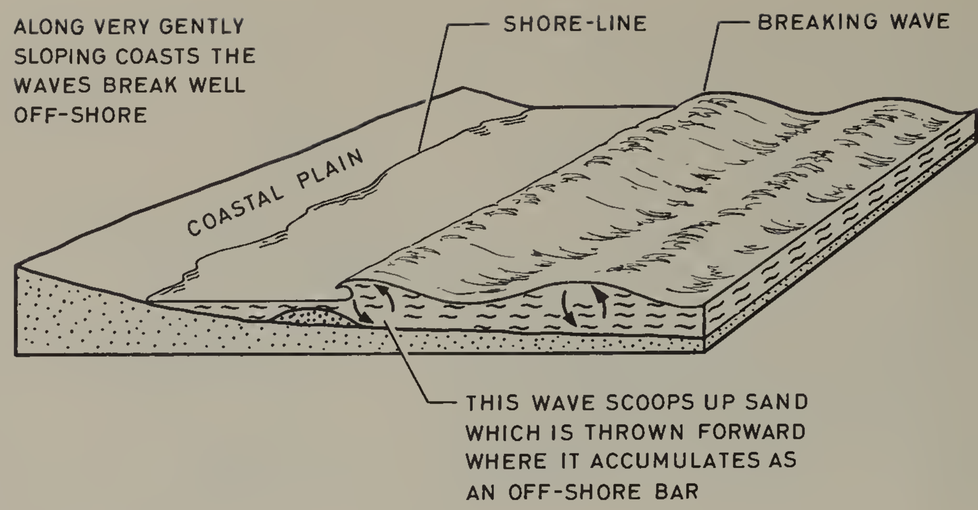
Chesil Beach is really a *tombolo* because it joins an island to the mainland.

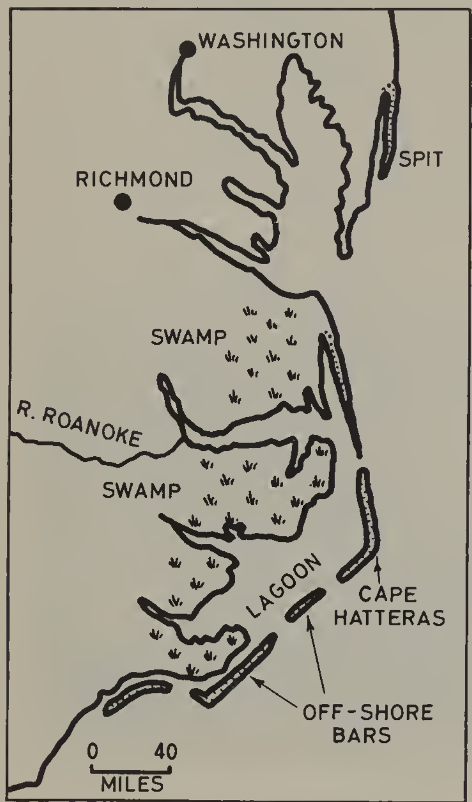
Coast of South Australia



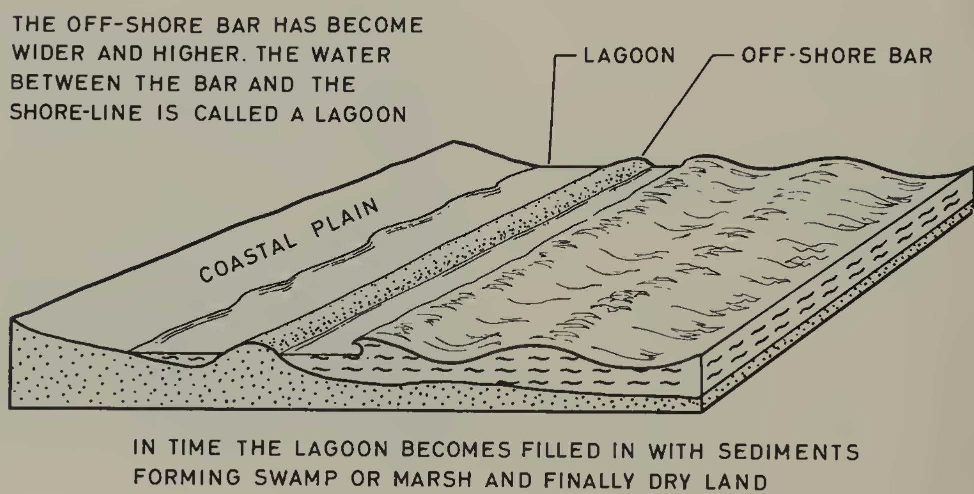
Coast of Victoria (Australia)

Off-shore Bar: This develops only along very gently sloping coasts such as the southern part of the Atlantic Coast of North America. The two diagrams on the right will help you to see how an off-shore bar can be built by wave action.





Part of the Atlantic Coast of North America



Types of Coasts

Neither the level of the land nor the level of the sea remains unchanged for long periods of time. During the last Ice Age the level of the sea was lower than it is today because large quantities of water were locked up in the ice masses which covered extensive parts of Europe and North America. The Ice Age was followed by a gradual return to warmer conditions and the ice sheets melted and their waters returned to the sea. The level of the sea rose and some coastal regions were submerged. Land masses too change their level. Sometimes coastal regions were depressed; sometimes they were uplifted. After the disappearance of the ice sheets parts of the land masses were slowly uplifted through the removal of the great weight of ice.

It will be seen that coastal regions may be either submerged or uplifted by changes in land or sea levels. There are therefore two basic types of coast: *submerged* and *emerged*. Each can be sub-divided into highland and lowland types to give:

Submerged Coasts
1 Highland type
2 Lowland type

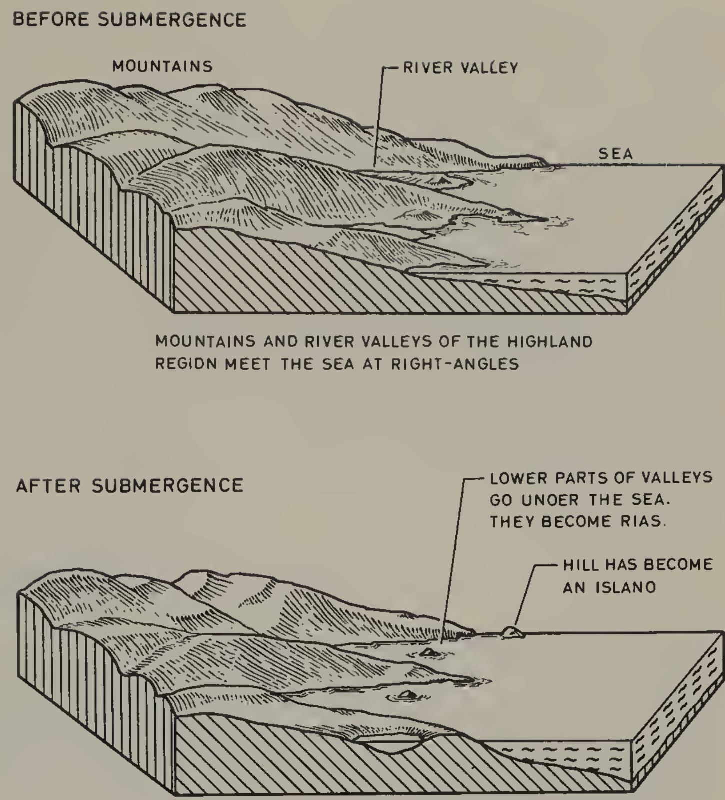
Emerged Coasts
1 Highland type
2 Lowland type

Submerged Highland Coasts

There are three main types:
1 Ria Coast
2 Longitudinal Coast
3 Fiord Coast

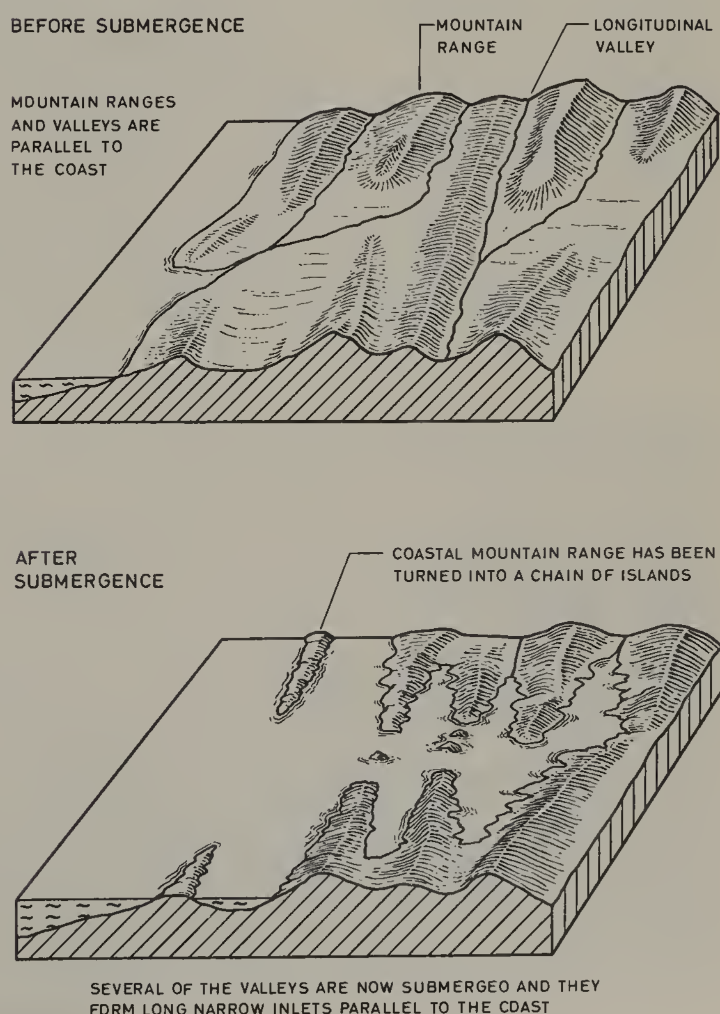
Ria Coast: When a highland coast is submerged the lower parts of its river valleys become flooded. These submerged parts of the valley are called rias. Such rias are common in S.W. Ireland, S.W. England, N.W. Spain, and Brittany.

After submergence the coast becomes indented and the tips of headlands may be turned into islands.



Ria Coast

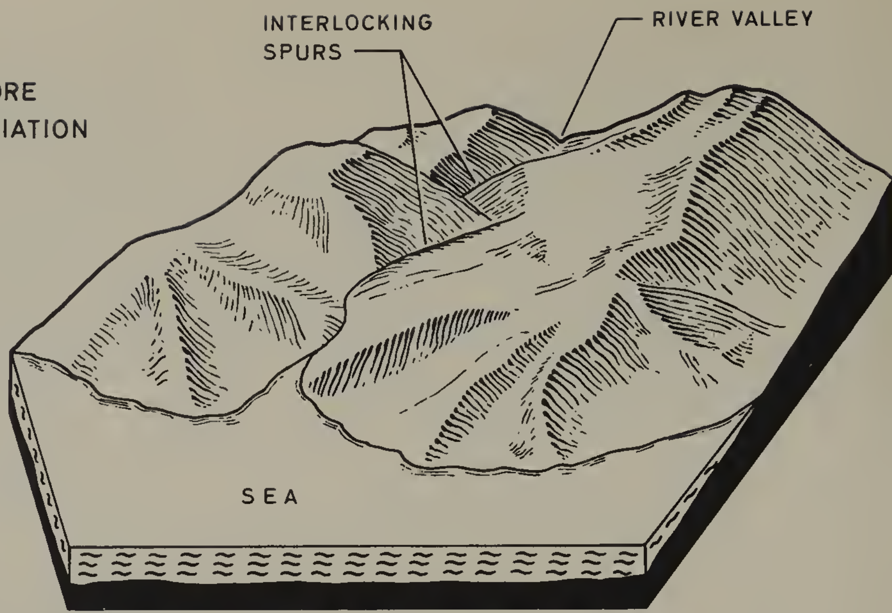
Longitudinal Coast: When a highland coast whose valleys are parallel to the coast is submerged, some of the valleys are flooded and the separating mountain ranges become chains of islands. These valleys are sometimes called sounds, e.g. Puget Sound in British Columbia. This type of coast occurs in Yugoslavia and along parts of the Pacific coasts of North and South America.



Longitudinal Coast

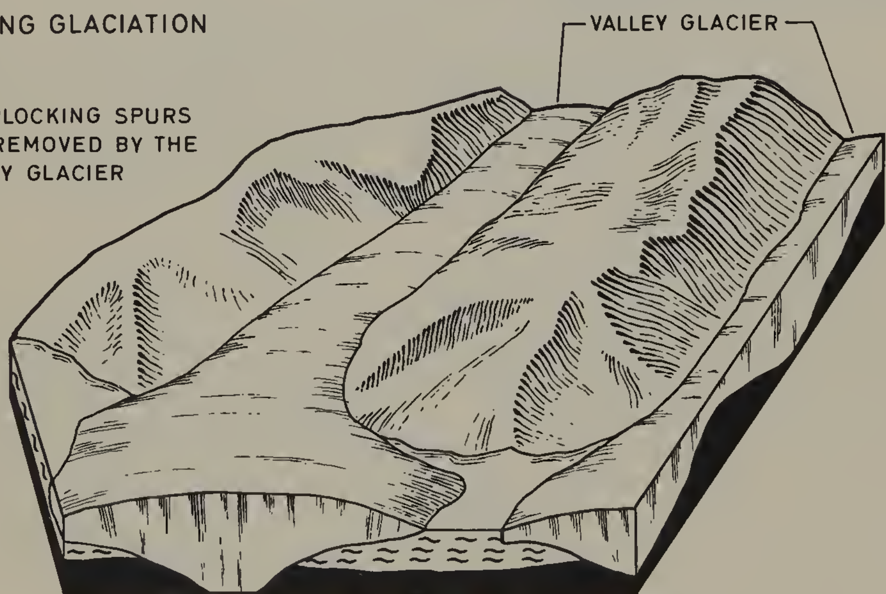
Fiord Coast: When glaciated highland coasts become submerged the flooded lower parts of the valleys are called fiords. These three diagrams show how the fiords have developed. During glaciation the river valleys become widened and deepened. After the glaciers have disappeared and the sea has risen the steep-sided valleys are 'drowned'. Notice that the water inside the fiord is much deeper than it is at the entrance of the fiord. Fiords have steeper sides and deeper water than rias.

BEFORE GLACIATION



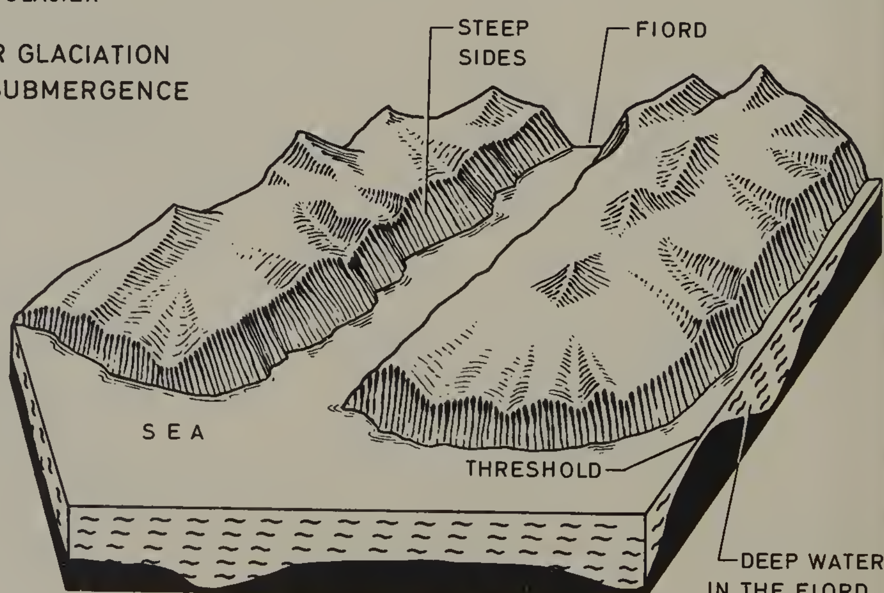
DURING GLACIATION

INTERLOCKING SPURS ARE REMOVED BY THE VALLEY GLACIER



THE RIVER VALLEY IS STRAIGHTENED, WIDENED AND DEEPENED (BELOW SEA LEVEL) BY THE GLACIER

AFTER GLACIATION AND SUBMERGENCE



VALLEY BECAME SUBMERGED. PARTLY CAUSED BY OVER DEEPENING, AND PARTLY BY A RISE IN SEA LEVEL

All the fiord coasts lie in the belt of prevailing westerly winds and are on the western sides of land masses. It was in these regions that vast amounts of snow and ice accumulated in the Ice Age. Some of the best examples of fiord coasts occur in Chile, South Island of New Zealand, Greenland, Norway and British Columbia.

Fiord Coasts of the World

The Value of Rias and Fiords to Man

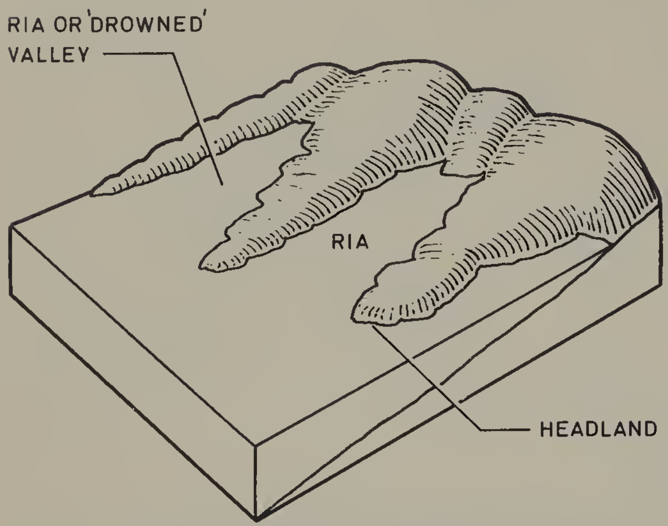
1 Both rias and fiords often provide natural 'harbours'.
2 It is often extremely difficult to get inland from the head of a fiord because of the mountainous country. A fiord, therefore, is not very useful as a site for a port.
3 It is usually easy to get inland from the head of a ria and because of this a ria is sometimes the site of a port.
4 Settlement is difficult along the sides of a fiord because there is little or no level land. Fiord settlements occur at the head of a fiord where there is level land.

Ria of the River Yealm on the South Devon Coast

Trollfiord in Northern Norway. Compare and contrast this with the photograph above

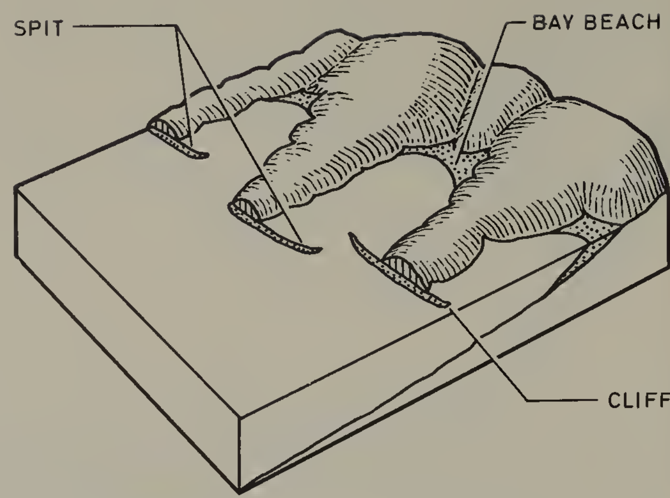
Wave Action Alters a Submerged Highland Coast

I. IN THE BEGINNING



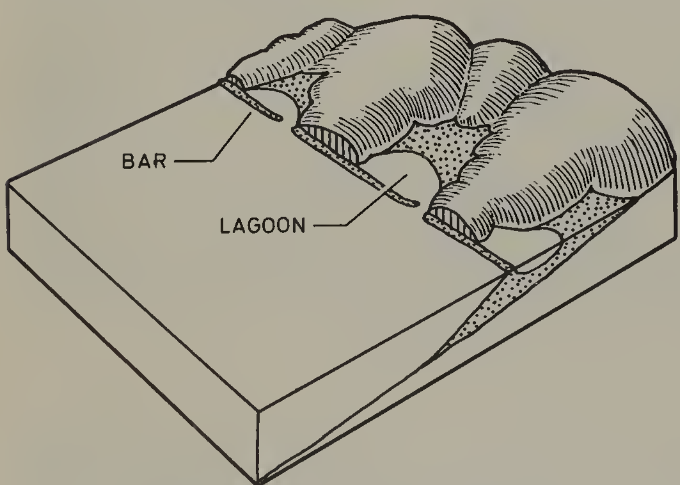
IRREGULAR COAST OF RIAS AND HEADLANDS. HEADLANDS ARE CUT BACK BY WAVE EROSION, AND CLIFFS, CAVES AND STACKS FORM

II. STAGE OF YOUTH



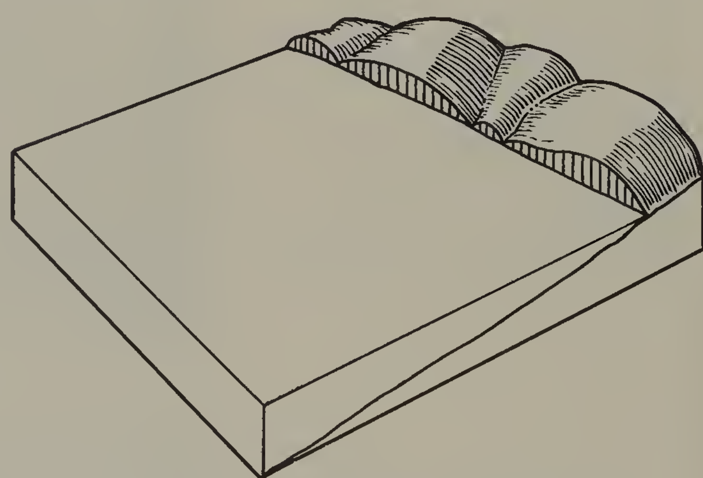
WAVE DEPOSITION IS MORE IMPORTANT THAN EROSION. SPITS AND BAY BEACHES ARE FORMED. THE COAST IS BECOMING STRAIGHTER FOR EROSION OF THE HEADLANDS STILL GOES ON

III. STAGE OF EARLY MATURITY



EROSION IS STILL CUTTING BACK THE HEADLANDS. BARS EXTEND ACROSS THE BAYS WHICH ARE NOW TURNED INTO LAGOONS. THESE ARE BEING FILLED IN WITH SEDIMENTS AND MARSHES FORM

IV. STAGE OF LATE MATURITY



THE COAST IS NOW CUT BACK BEYOND THE HEADS OF THE BAYS, AND IT IS NOW ALMOST STRAIGHT

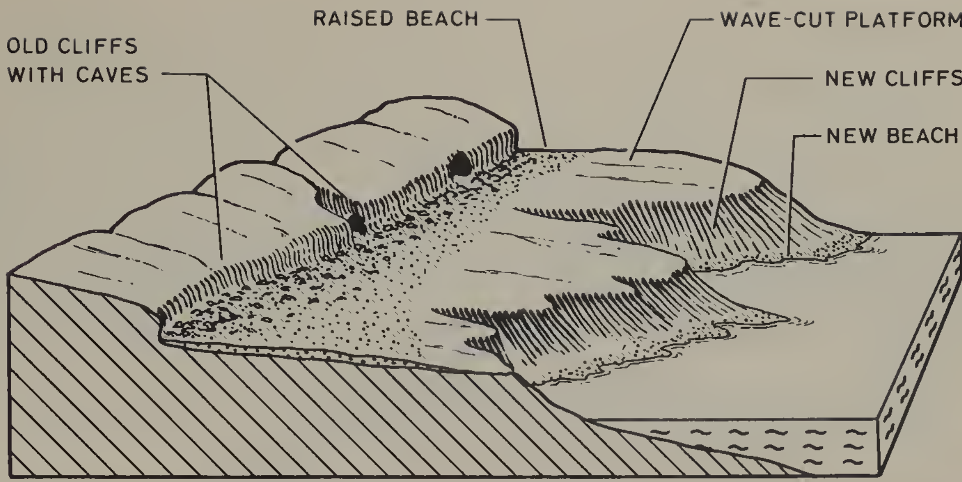
Submerged Lowland Coast

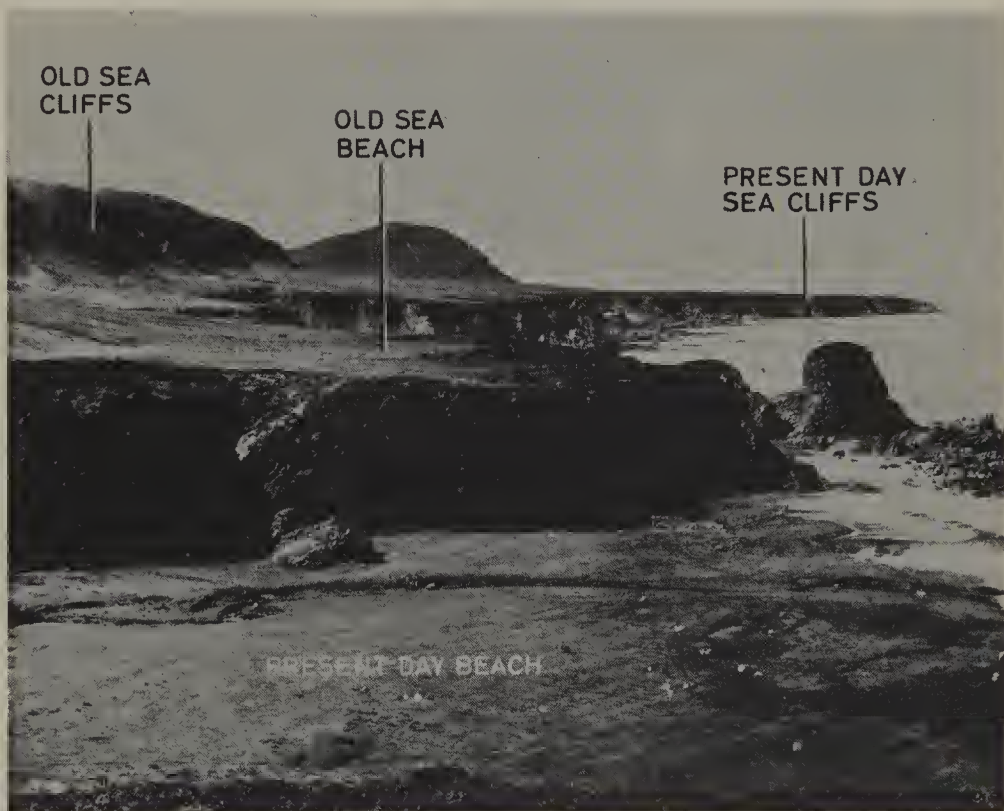
A rise in sea level along a lowland coast causes the sea to penetrate inland along the river valleys, often to considerable distances. The flooded parts of the valleys are called *estuaries*. Marshes, swamps and mud flats can often be seen in estuaries at low tide. The Baltic coasts of Poland and Germany and the Dutch coast are good examples of estuarine coasts.

Emerged Coasts

Highland Coast

An old sea beach backed by a sea cliff lying from 25′ to 100′ above sea level often characterises this type of coast. These two features could only have been produced by sea action, but, since the sea no longer reaches them, it is evident that there has been a change in either sea level or the level of the land. Raised beaches are common in Western Scotland.

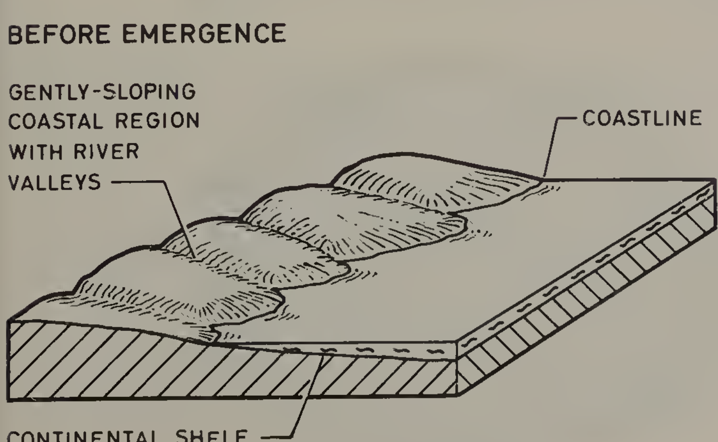


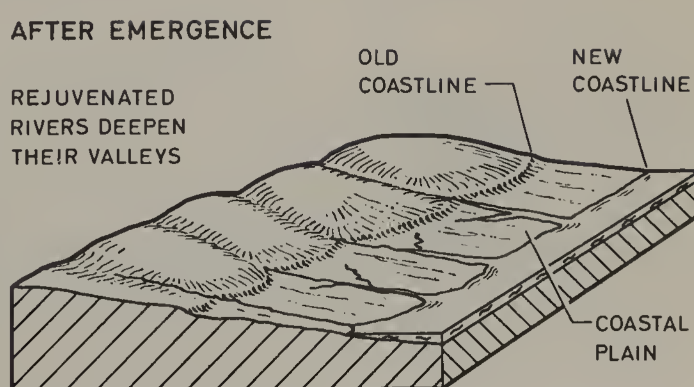


Raised Beach in Scotland

Lowland Coast

This forms when a part of the continental shelf emerges from the sea and forms a coastal plain. The coast has no bays or headlands and deposition takes place in the shallow water off-shore, producing off-shore bars, lagoons, spits and beaches. Examples of this type occur along the south-east coast of U.S.A. and the north coast of the Gulf of Mexico. The development of ports is difficult.





UPLIFT OF THE LAND STEEPENS THE GRADIENTS OF THE RIVERS AND THEY DEEPEN THEIR VALLEYS. THE RIVERS ARE SAID TO BE REJUVENATED (MADE YOUNG AGAIN)

Coral Coasts

Nature of Coral. It is a limestone rock made up of the skeletons of tiny marine organisms called coral polyps. The tube-like skeletons in which the organisms live extend upwards and outwards as the old polyps die and new ones are born. Coral polyps thrive under these conditions:

1 sea temperature about 70°F
2 sunlit, clear salt water.

Extensive coral formations develop between 30°N and 30°S on the eastern sides of land masses where there are warm currents, but not on the western sides where there are cool currents.

Types of Coral Formation

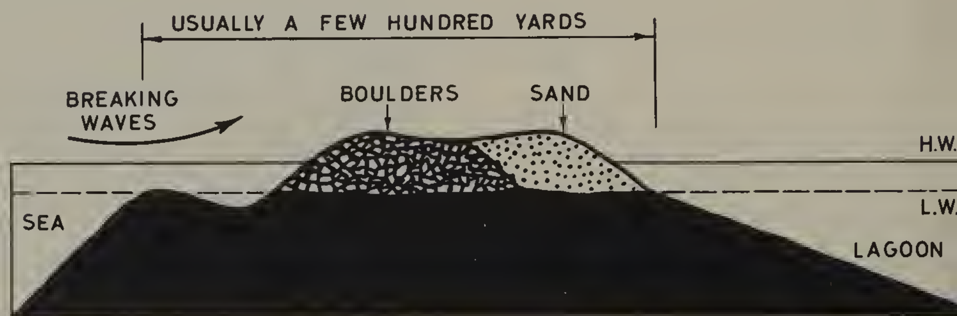
Coral masses are called reefs and there are three types:

1 *Fringing Reef:* a narrow coral platform separated from the coast by a lagoon which may disappear at low water.
2 *Barrier Reef:* a wide coral platform separated from the coast by a wide, deep lagoon.
3 *Atoll:* a circular coral reef which encloses a lagoon.

Structure of a Coral Reef

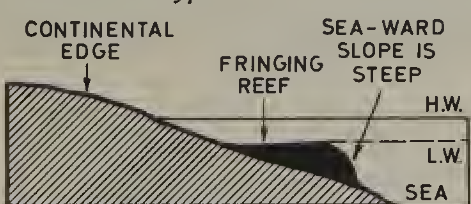
Most reefs are fairly narrow and the coral platform lies near to low water level. The seaward edge is steep and pieces of coral broken off by wave action are thrown up onto the platform where they form a low mound. On the landward side of this the breaking waves deposit sand in which the seeds of plants, such as coconut, readily germinate. Coral atolls in the Pacific are of this type.

Section across a Coral Reef

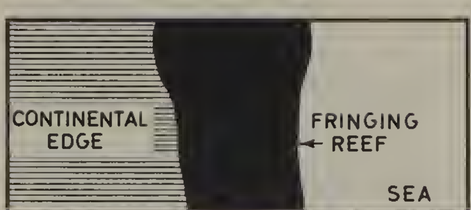


Fringing Reef

Continental Type



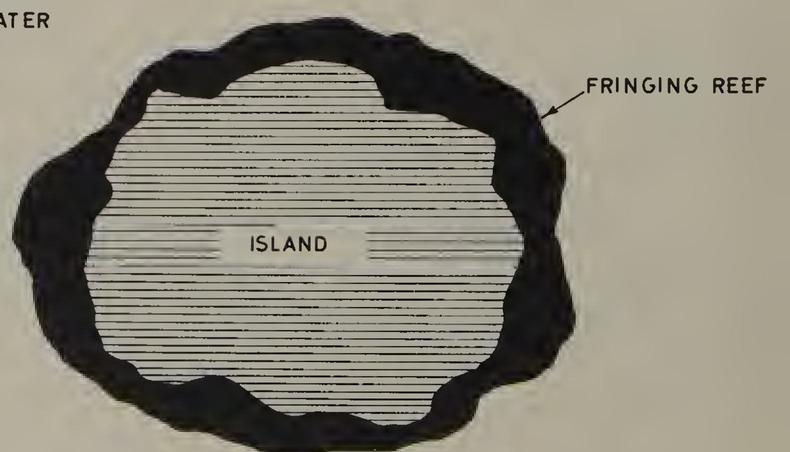
H.W. HIGH WATER
L.W. LOW WATER



In this type of reef the coral is exposed at low water.

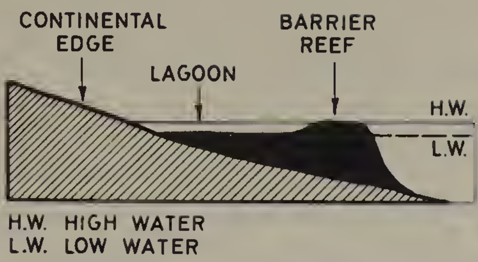
Island Type

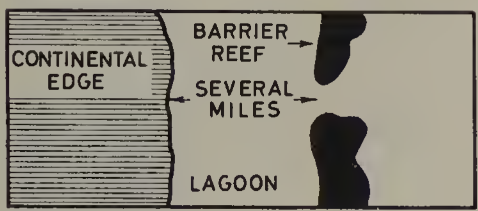
H.W. HIGH WATER
L.W. LOW WATER



Barrier Reef

Continental Type





In this type of reef the coral is rarely exposed at low water. The largest barrier reef in the world extends along the east coast of Australia for nearly 1,200 miles.

Island Type

Atoll

The diagram on the right is a drawing of a typical atoll. Atolls are particularly common in the Pacific and Indian Oceans. Some atolls are very large, e.g. that of *Suvadiva* in the Maldives. The lagoon of this atoll is 40 miles across and its reef extends for 120 miles. The Gilbert and Ellice Islands of the Pacific are all atolls.

An Atoll in the Pacific Ocean

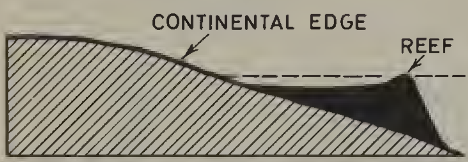
The Origin of Coral Reefs

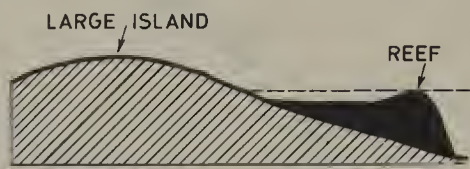
Many theories have been put forward to explain the origin of reefs, and in common with so many theories explaining the possible origin of other landforms, no one can say which is the true one. All that we can do is to examine these theories and accept that which sounds the most reasonable.

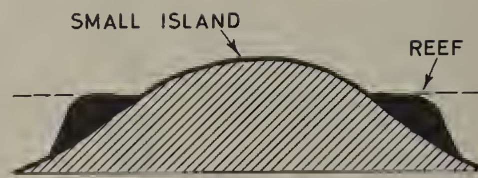
Theory I (this is based on the changing level of the sea during and after the last Ice Age).

Fringing Reef | *Barrier Reef* | *Atoll*

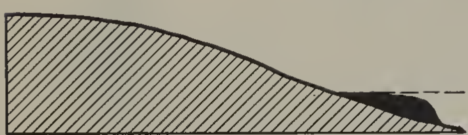
BEFORE THE ICE AGE



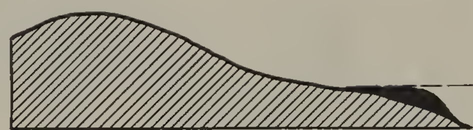




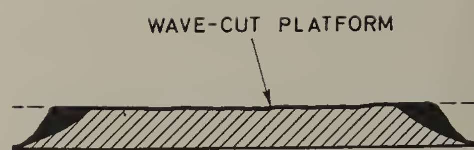
DURING THE ICE AGE



As sea level fell wave erosion removed most of the reef.

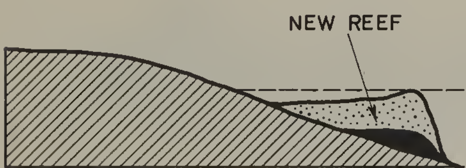


As sea level fell wave erosion cut a terrace into the reef and the edge of the island.

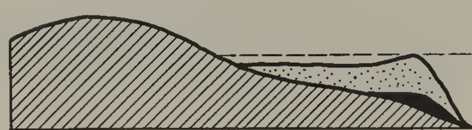


As sea level fell wave erosion removed the top of the island and turned it into a wave-cut platform.

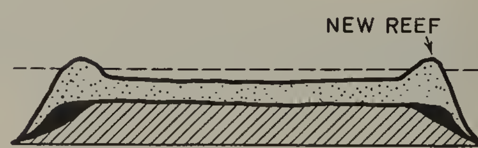
AFTER THE ICE AGE



A rising sea level plus a return to warmer conditions caused the reef to grow up and form a barrier reef.



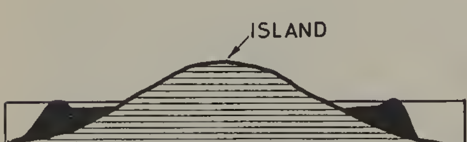
A rising sea level plus a return to warmer conditions caused the reef to grow up again.



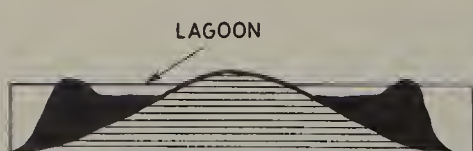
A rising sea level plus a return to warmer conditions caused the reef to grow up again and form an atoll.

Theory II (this depends on the subsidence of land masses).

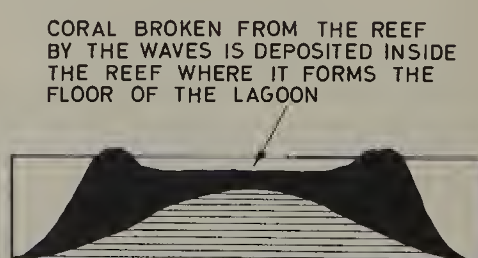
Fringing Reef



Barrier Reef



Atoll



As the island subsides the coral reef grows upwards and outwards keeping pace with the subsidence. According to this theory fringing reefs pass into barrier reefs which in turn pass into atolls. This theory was first suggested by Charles Darwin.
The two theories mentioned above can only be used with reference to coral island reefs.

Ice Action and the Features it Produces

When the temperature of the air falls below 32°F some of the water vapour condenses and freezes into ice crystals which fall to earth as *snow*. Many regions in the high latitudes receive snow in the winter season but in most of them the snow melts in the following summer. If some of it fails to melt then a perpetual cover of snow results. This happens in Greenland, Antarctica and on the tops of some high mountains. The level above which there is a perpetual snow cover is called the *snowline*. The height of this ranges from sea level around the Poles to 18,000′ in the mountains of East Africa which are on the equator.

When the accumulation of snow in a region increases from year to year it gradually turns into ice by its own weight. About 1,000,000 years ago the climates of regions in the high latitudes began to get colder and colder and not all of the winter snowfall melted in the following summers. The accumulations of snow increased in area and in depth in the polar regions, in the northern part of North America and the north-western part of Europe. The snow of these vast *snow fields* gradually turned into ice which extended over most of the lowlands and some of the mountains. Masses of ice which cover large areas of a continent are called *ice sheets*, and those which occupy mountain valleys are called *valley glaciers*. Today ice sheets occur in Antarctica and Greenland, and valley glaciers in the Himalayas, Andes, Alps and Rockies. The period when the high latitudes were buried beneath ice sheets is known as the *Ice Age*. With the return to warmer conditions most of the ice melted. However, there are still extensive regions around the Poles and smaller areas in the mountain systems named above which still have glaciers, and these regions are therefore still in the Ice Age.

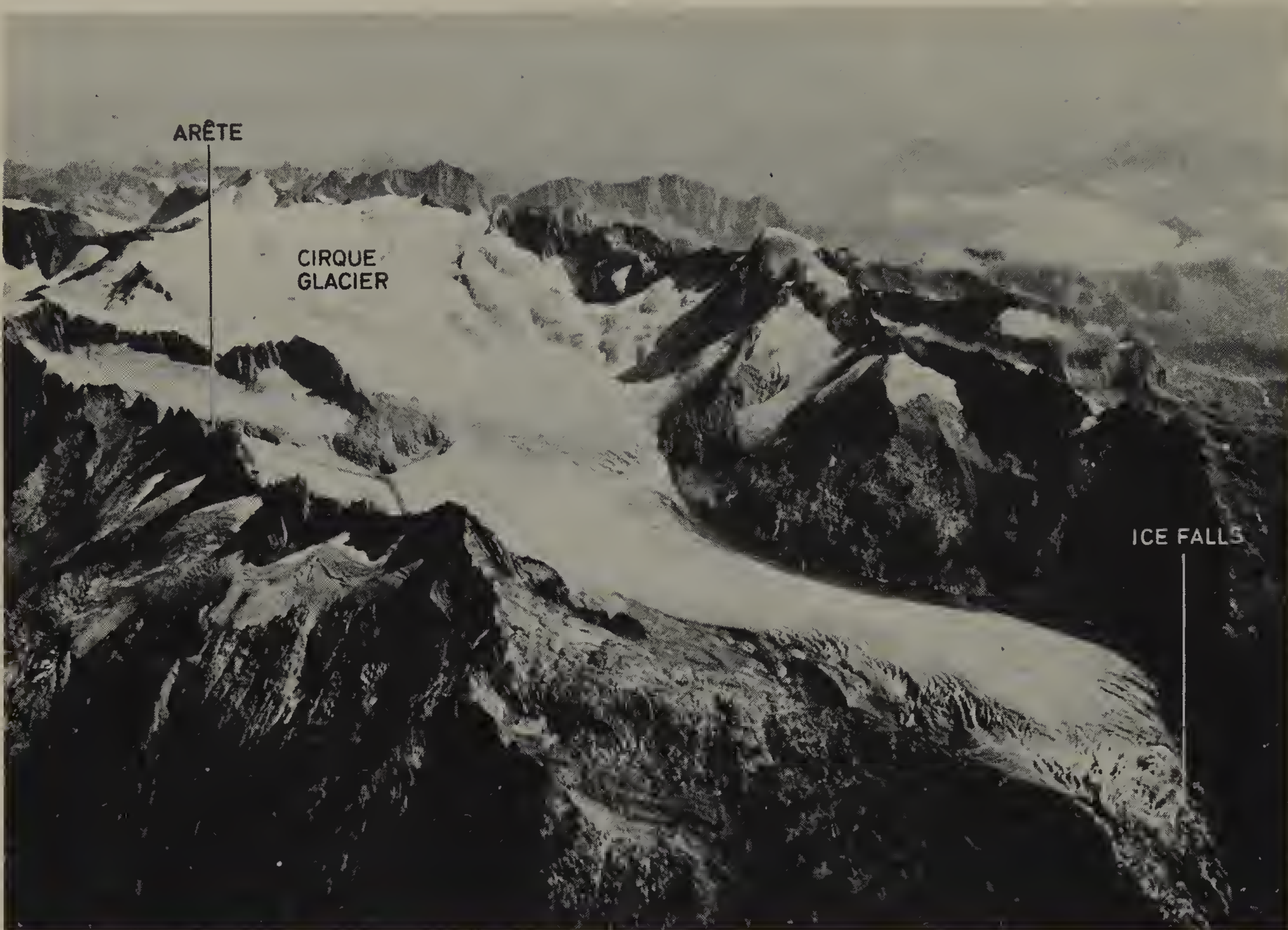
Ice action greatly changes the appearance of a region. Highlands are subjected to erosion and lowlands to deposition. In many parts of the northern continents which are now free from ice, striking features of both glacial erosion and deposition can be clearly seen. With the melting of the ice at the end of the Ice Age enormous quantities of water were set free. Some of this collected in hollows or was held back by glacial deposits (called *moraine*) and formed lakes. The Great Lakes of North America and the lakes of Finland were formed in this way. Most of the melt waters however flowed as rivers into the sea. These rivers carried large quantities of morainic deposits which were later spread over the land outside the regions which lay under the ice. Here the deposits formed extensive plains called *outwash plains*. These are usually very sandy.

Glacial Erosion and the Features it Produces

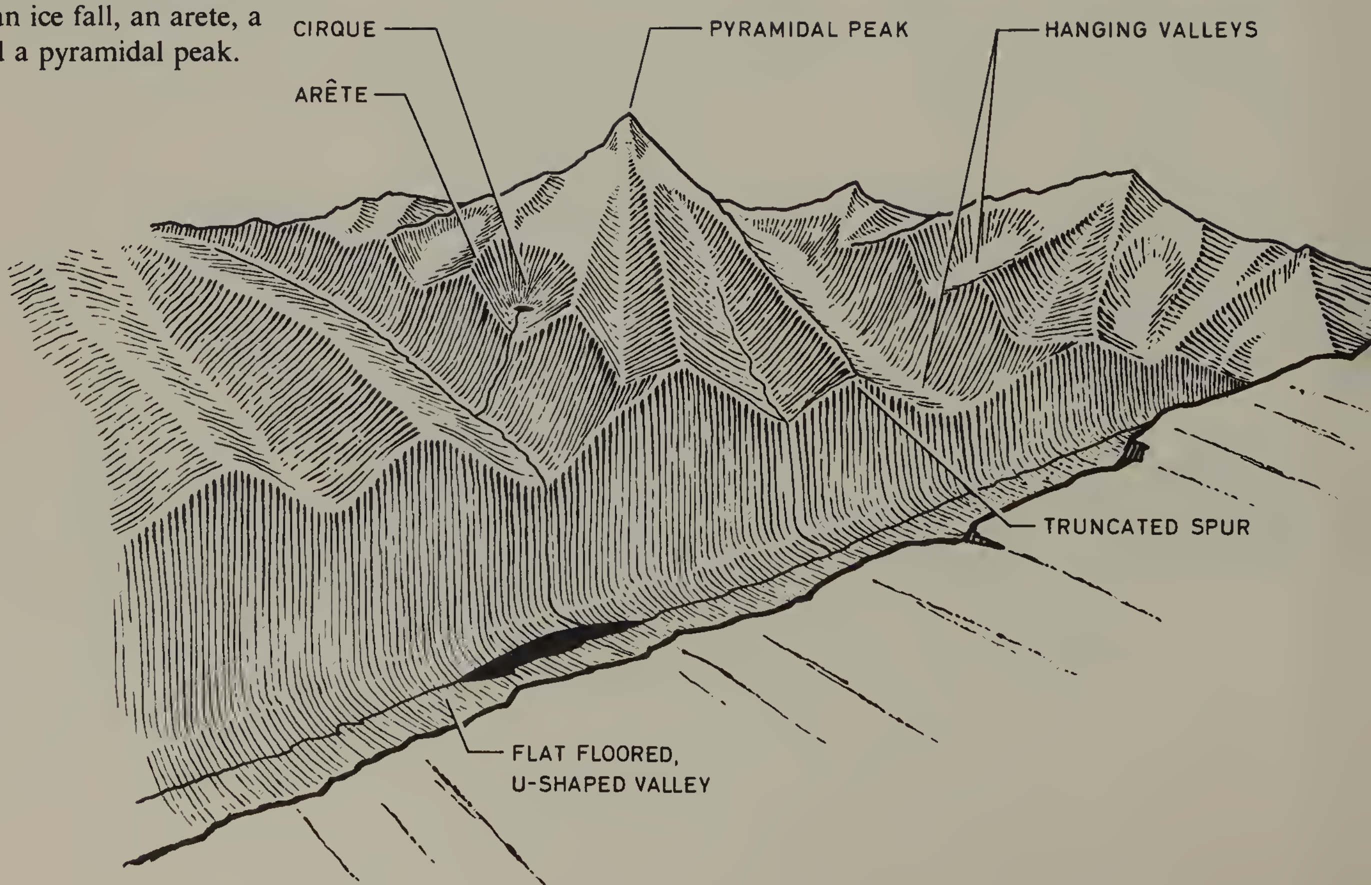
Glacial Erosion. Consists of two processes: (i) *plucking* (the tearing away of blocks of rock which have become frozen into the base and sides of a glacier), and (ii) *abrasion* (the wearing away of rocks beneath a glacier by the scouring action of the rocks embedded in the glacier).

Erosional Features. The most important of these are: *U-shaped valley*; *hanging valley*; *cirque* (corrie); *arete*; *pyramidal peak*. These features are chiefly produced by valley glaciers. Study diagram on page 92.

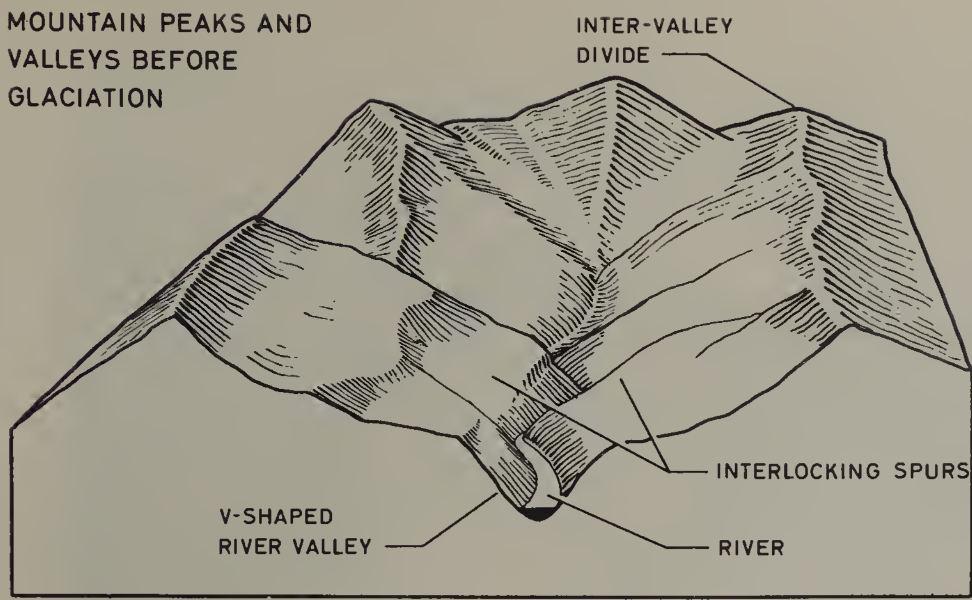
The Rhone Glacier in Switzerland

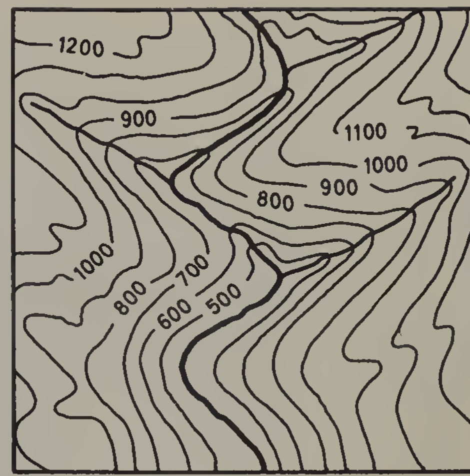


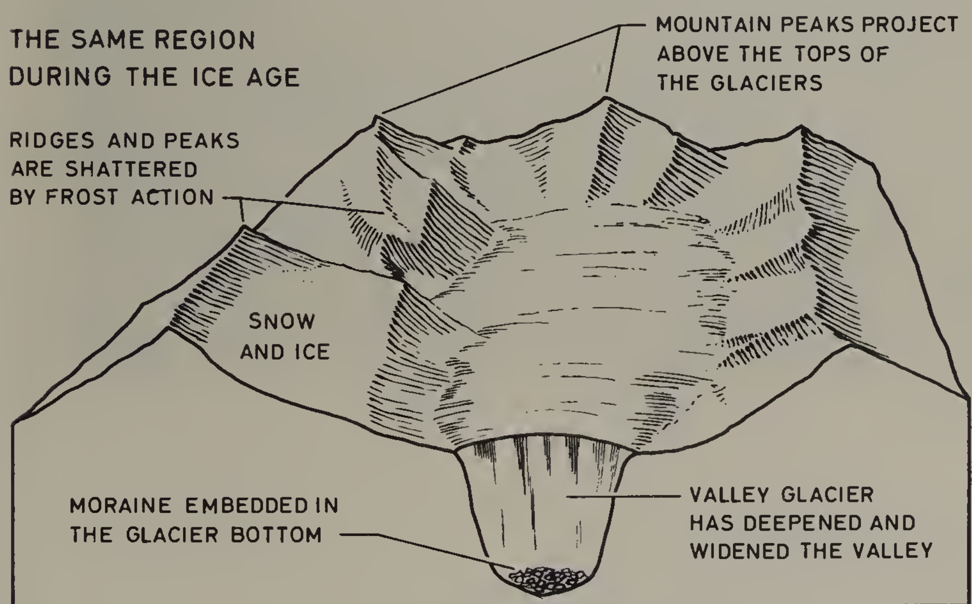
The glacier is fed by the snow field which occupies the upper basin. Try to locate an ice fall, an arete, a cirque and a pyramidal peak.



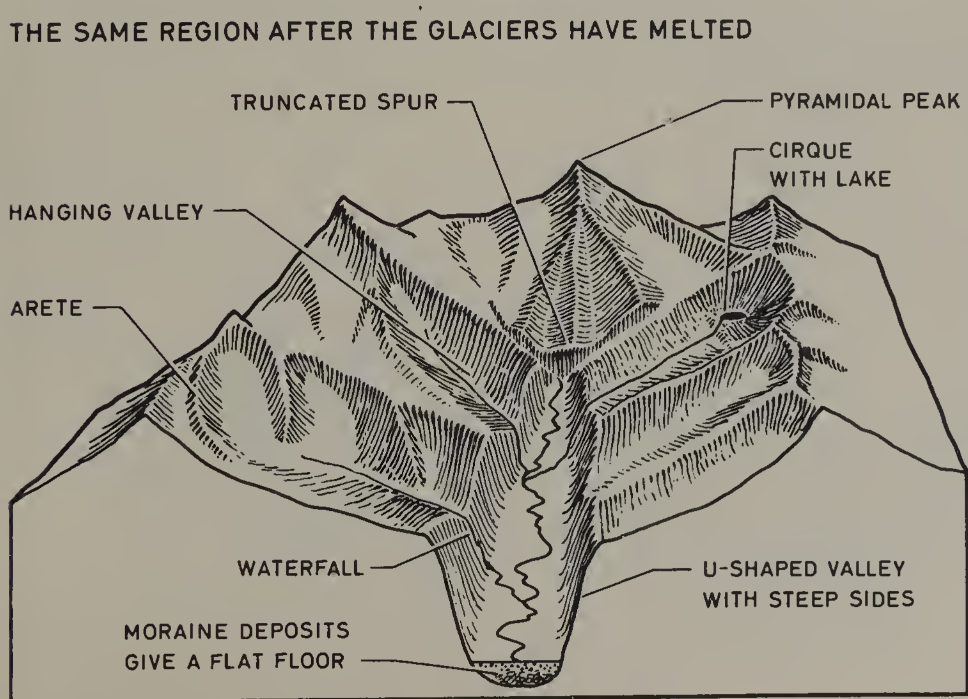
U-shaped Valley

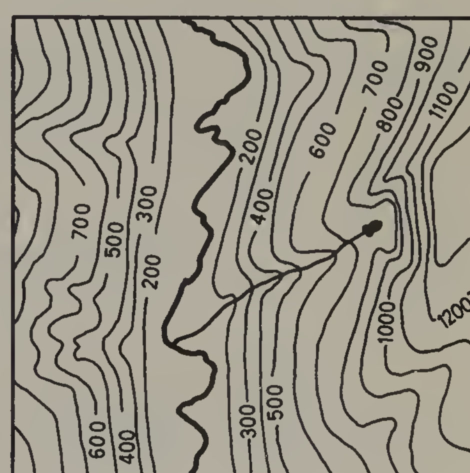






These diagrams show how a glaciated valley may have formed. The glacier deepens, straightens and widens the river valley whose interlocking spurs become truncated or cut back. Inter-valley divides are sharpened to give aretes and pyramidal peaks. Examine the two contour maps and compare these with their respective block diagrams.



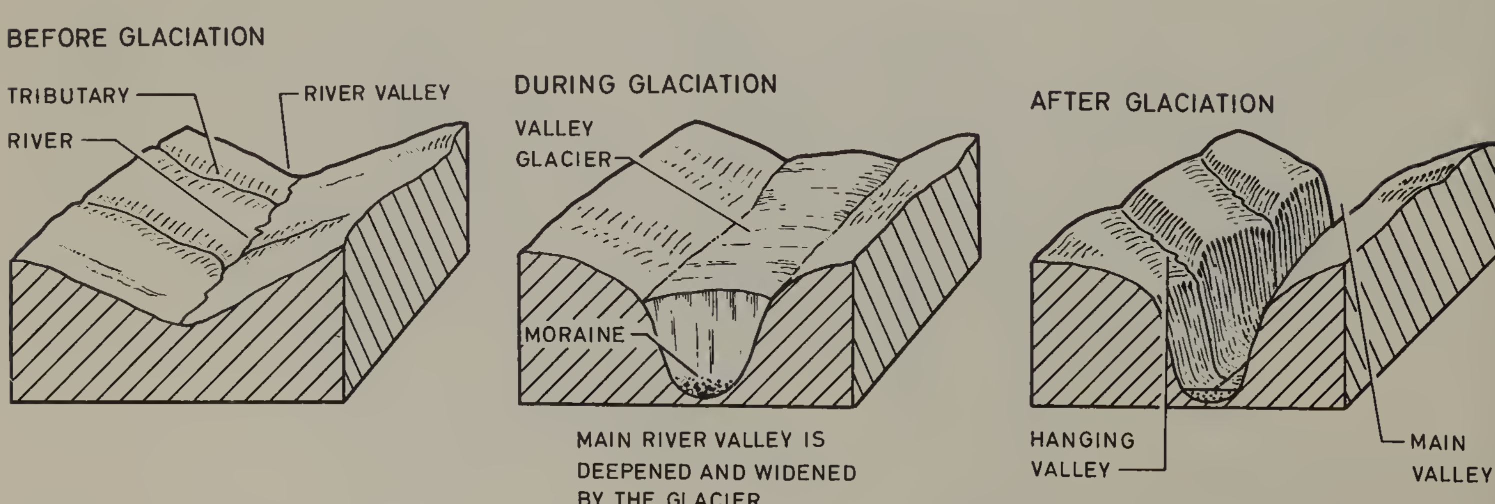


The Lauterbrunner Valley in Switzerland

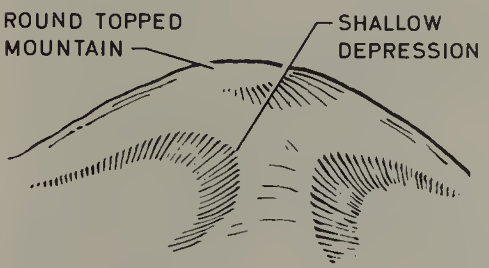
Identify four important features in this valley which have been produced by glacial action.

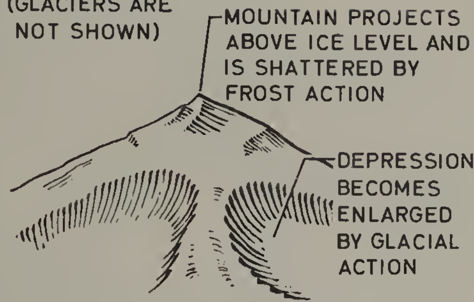
Hanging Valleys

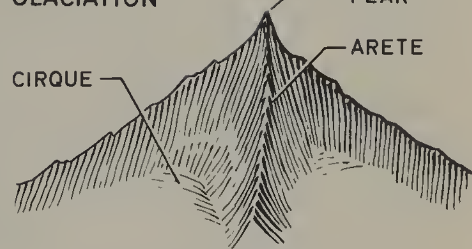
The tributary valleys of most glaciated U-shaped valleys are perched high upon the valley sides as shown in the diagram on the right. The streams of these valleys join the main river via waterfalls, and the valleys are called *hanging valleys*. Such valleys have probably been caused by the over-deepening of the main valley by a glacier (centre diagram). At the same time tributary valleys contained either small glaciers or no glaciers at all with the result that these valleys received little deepening.

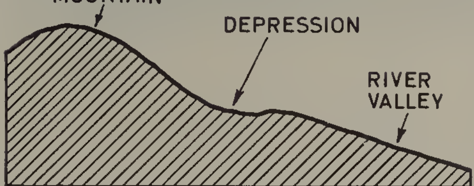


Cirques, Aretes and Pyramidal Peaks
Glaciers enlarge and deepen initial hollows at the heads of valleys high up on mountain slopes and turn them into cirques.

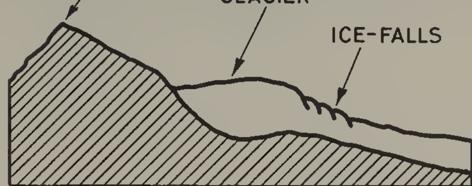




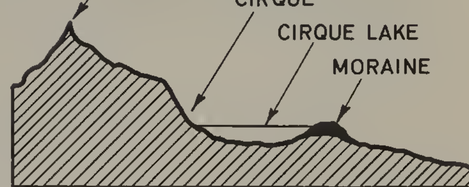




An arete forms where two cirques meet. When three or more cirques meet, a pyramidal peak develops.



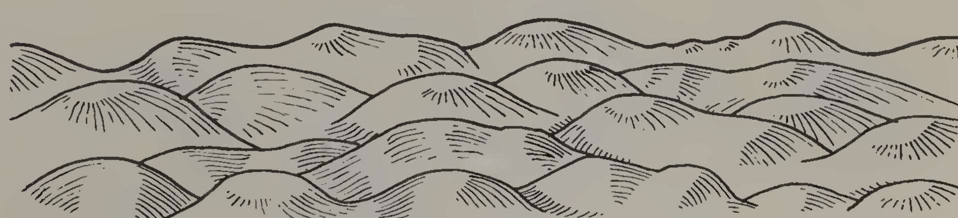
The glacier in a cirque extends down the valley as a valley glacier.



A cirque often contains a lake which may in part be caused by the damming effect of a moraine.

When mountain ranges are buried beneath ice sheets, their peaks and jagged slopes are smoothed off as shown in the two bottom diagrams. Compare these mountains with those of the diagram at the bottom left of page 93 which projected above the level of the glaciers and which were shattered by frost.

APPEARANCE OF MOUNTAINS BEFORE CONTINENTAL GLACIATION



APPEARANCE OF MOUNTAINS AFTER CONTINENTAL GLACIATION

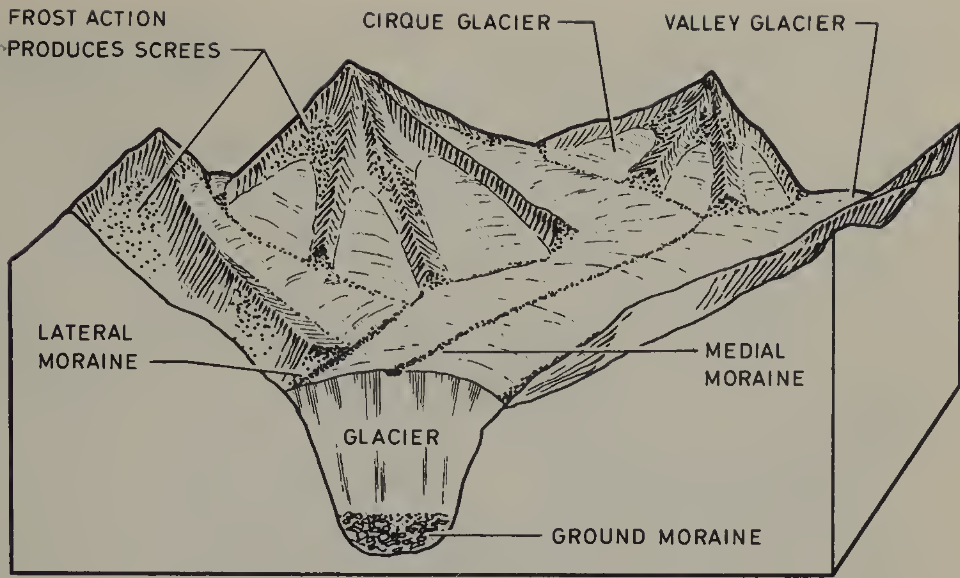
The Dent Blanche in Switzerland. Mt. Bernina and Mt. Roseg

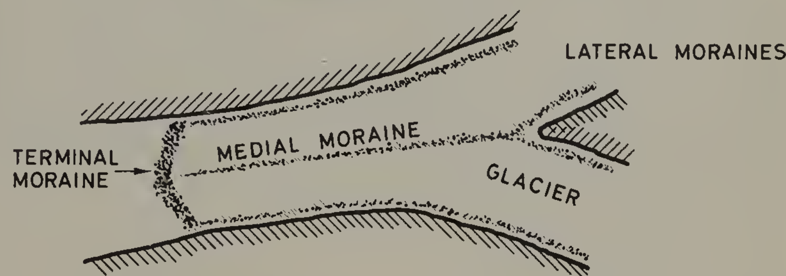
This photograph shows a pyramidal peak, cirques and aretes. The cirques contain snow fields. The glacier of the cirque in the foreground forms ice falls as it enters the valley below the cirque. Notice the sharpness of the arete on the right.

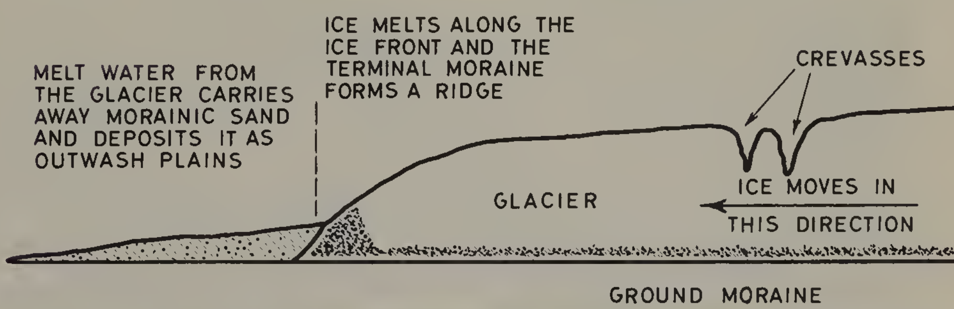
The Mourne Mountains in Ireland—compare with the photograph above

Glacial Deposition and the Features it Produces

A glacier carries large quantities of rock waste which is called moraine. Some of this has been torn from the valley bottom by the glacier and is embedded in its bottom and sides. The rest has fallen from the mountain slopes where it accumulated under frost action. The moraine along the sides of the glacier is called lateral moraine; that along the front of the glacier is called terminal moraine, and that at the bottom of the glacier is called ground moraine. In the top diagram there is a medial moraine. This has been formed by the union of the lateral moraines of two glaciers.







Examine the photograph of the Nabesna Glacier in Alaska and see how many of these features you can recognise:

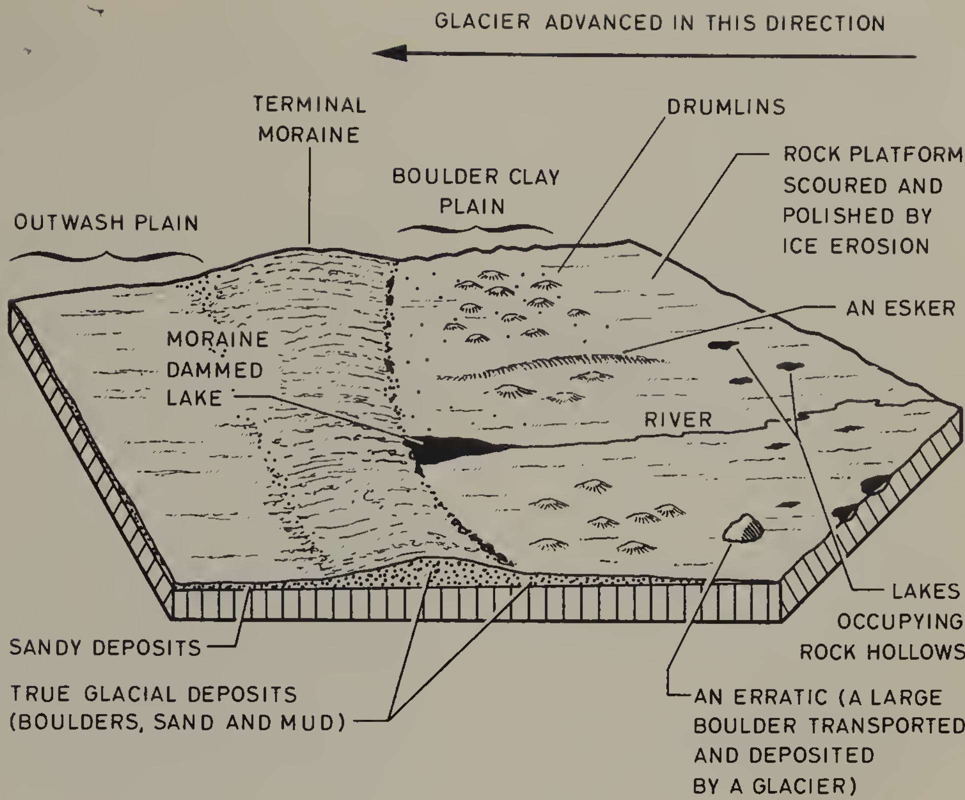
(i) medial moraine
(ii) truncated spur
(iii) hanging valley
(iv) cirque
(v) pyramidal peak
(vi) arete
(vii) snow field
(viii) lateral moraine.

Nabesna Glacier in Alaska

Mer de Glace in the French Alps
This glacier is 3½ miles long and at its end the melt waters give rise to a river. How many glacial features can you recognise on this photograph?

A very impressive terminal moraine develops when the glacier front remains stationary for a long time (bottom diagram, page 97). As the climate gets warmer a glacier melts and finally disappears. Of course this takes a very long time, but eventually all the glacier's moraines are deposited. These produce a variety of landforms, and these are shown in the diagram on page 99. Remember this is only a diagram—in nature the landforms are often very mixed up. The melt waters along the glacier front carry away vast amounts of fine morainic material which is later deposited as outwash plains. These contain a good deal of fine rock particles and sand and are more like river deposits than glacial deposits. True glacial deposits are unsorted, i.e. rock particles of all shapes and sizes are mixed up together. If the melt waters take the form of a river then the morainic material is deposited as a delta at the ice front. If the front is retreating fairly quickly then the delta becomes elongated and forms a ridge which is called an esker—page 99.

Glacial depositional features are formed by both valley glaciers and ice sheets. Ground moraine gives rise to uneven sheets of clay with boulders. This is often referred to as boulder clay.



This is what an ancient shield looks like after it has been glaciated. Rock hollows containing lakes, eskers and terminal moraines, often covered with pine trees, characterise the landscape.

The Lake Plateau of Finland

The Value of Glaciated Regions to Man

I *Glacial Features of Value to Man*

(i) Boulder clay plains are sometimes very fertile, e.g. East Anglia in Great Britain and parts of the Dairy Belt of North America.

(ii) Old glacial lake beds are invariably fertile. Extensive areas of the Canadian Prairies producing vast amounts of wheat each year owe their prosperity to the rich alluviums which once collected on the floors of glacial lakes.

(iii) Some glacial lakes, e.g. the Great Lakes of North America, are of real value as natural routeways.

(iv) Waterfalls issuing from hanging valleys are sometimes suitable for the development of hydro-electric power. Both Norway and Switzerland develop large amounts of H.E.P. from such waterfalls.

(v) Glaciated mountain regions attract tourists, especially during the winter season when heavy snowfalls make skiing and other sports possible.

(vi) Some glacial lakes have cut deep overflow channels where they have drained away. Some of these channels today form excellent routeways across difficult country, e.g. the Hudson-Mohawk Gap which leads down to New York.

(vii) Many glaciated valleys have benches or 'alps' high up on their sides. During the summer these 'alps' have good pasture, but during the winter they are covered with snow. Cattle are grazed on the alpine pastures during the summer and are brought down to the sheltered valley bottom pastures during the winter. This movement of animals is called *transhumance*, and it goes on in Switzerland, Norway and other mountainous countries.

II *Glacial Features of Little Value to Man*

Now let us look at the disadvantageous aspects of glaciation.

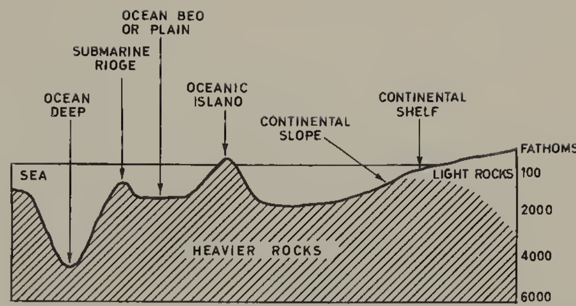
(i) Boulder clay deposits in some regions, e.g. Central Ireland, have produced a marshy landscape which is of little or no value to agriculture.

(ii) Many outwash plains contain infertile sands which give rise to extensive areas of waste land. It is true that this is sometimes of recreational value, but from an agricultural standpoint such regions are negative.

(iii) Extensive areas of land are sometimes turned into myriads of lakes by morainic deposits. Such lake landscapes offer little scope for development by Man.

Chapter 4 The Oceans

The oceans and seas together cover about 70 per cent of the world's surface. There are five oceans and all are joined with one another. These are: *Southern Ocean*; *Indian Ocean*; *Pacific Ocean*; *Arctic Ocean*; *Atlantic Ocean.*



Generalised section across an ocean floor

Nature of the Ocean Floor

Ocean floors, like continental surfaces, have relief features the chief of which are shown in the diagram. The edges of continents slope gently downwards under the surrounding oceanic waters. This part of the ocean floor is called the *continental shelf*. Along some coasts it is so narrow as to be almost absent. The best developed continental shelves are shown in the diagrams on page 102. Seawards of the shelf the ocean floor slopes more steeply, and this part of the floor forms the *continental slope*. The bed of the ocean sometimes rises up to give *ridges* some of which may appear above the surface of the ocean as *oceanic islands*. Below the ocean bed there are troughs and basins which are known as *deeps* or *trenches*. All the slopes shown in the diagram are greatly exaggerated but the depths given are true.

Note Do not confuse *oceanic islands* with *continental islands*. The latter rise from the continental shelf.

Continental Shelves of the World

Northern Hemisphere

Eurasia

1 Along the coast of N.W. Europe
2 Along the coast of Siberia
3 Below the Yellow Sea
4 Below the Java Sea and the southern part of the S. China Sea

North America

1 Along the north-east coast of North America
2 Below Hudson Bay
3 Along the Gulf Coast of North America

Southern Hemisphere

Australasia

1 Below the Gulf of Carpentaria
2 Below the Australian Bight

South America

1 Along the coast of Patagonia

Africa

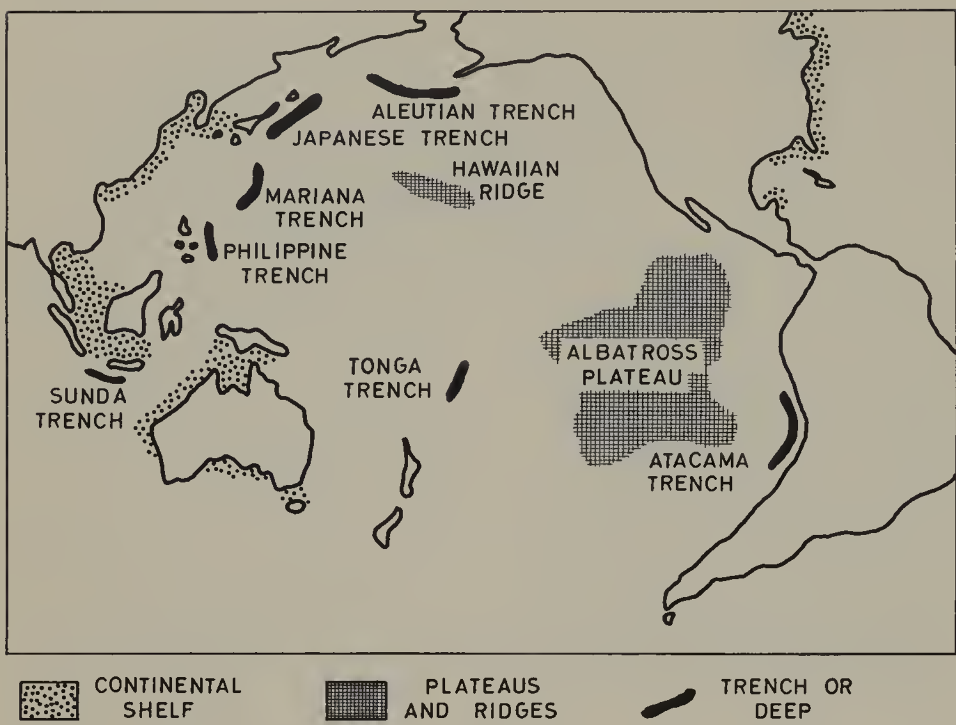
Very poorly developed

Value to Man

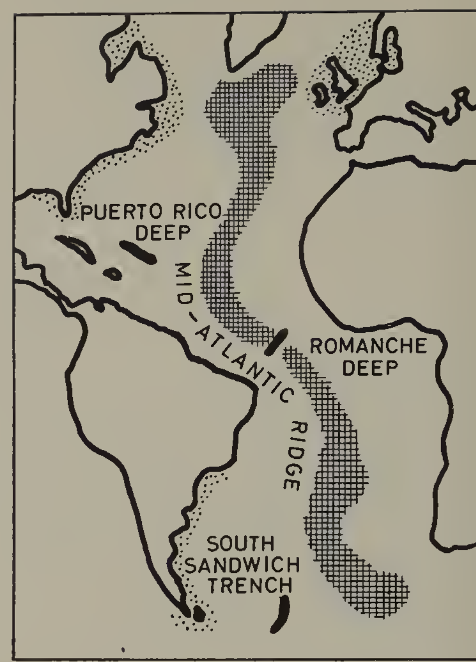
1 Sunlight easily penetrates the seas on continental shelves, and therefore there is an abundance of *plankton* which usually results in an abundance of fish.
2 They increase the height of tides thus improving shipping facilities.

Ocean Deeps and Ridges (they all lie below 2,000 fathoms)

Pacific Ocean



Atlantic Ocean



Notice how the deeps flank the east coast of Asia, and compare the location of the deeps with the location of Young Fold Mountains (diagram, page 28) and of volcanoes (diagram bottom of page 36).

Deeps	Ridges
Pacific Ocean	
1 *Mariana Trench* (5,940 faths.)	1 *Hawaiian Ridge*
2 *Philippine Trench* (5,900 faths.)	2 *Albatross Plateau*
3 *Tonga Trench* (5,150 faths.)	
4 *Japanese Trench* (4,650 faths.)	
5 *Aleutian Trench* (4,190 faths.)	
Atlantic Ocean	
1 *Puerto Rico Deep* (4,812 faths.)	1 *Mid-Atlantic Ridge* (arising from this are the oceanic islands of the *Azores*, *Tristan da Cunha* and *Ascension*)
2 *Romanche Deep* (4,030 faths.)	
3 *South Sandwich Trench* (4,545 faths.)	
Indian Ocean	
1 *Sunda Trench* (4,070 faths.)	1 A ridge extending from S. India to Antarctica

The Nature of Salt Water

Salinity

Sea water contains mineral salts. Two importants salts are sodium chloride ($NaCl$) and calcium bicarbonate ($Ca(HCO_3)_2$). The latter provides marine organisms with calcium carbonate ($CaCO_3$) which is necessary to the formation of shells and bones. When water evaporates the salts are left behind. The saltiness of a sea depends upon the amount of evaporation taking place from its surface, and the amount of fresh water brought into it by rivers. The *Mediterranean* and *Red Seas* are more salty than the oceans because they are located in regions of high temperatures and few rivers discharge into them. The *Black* and *Baltic Seas* are much fresher than the oceans. These seas are located in regions of low temperatures and fresh water is brought into them by rivers and melting ice. Inland seas like the *Great Salt Lake* (N. America) and the *Dead Sea* (Jordan) are very salty indeed.

Temperature

Water is heated by the sun's rays much more slowly than is land. It also loses heat to the air more slowly than does land. This causes the temperature of sea water to vary only slightly from season to season. The temperature of surface sea water ranges from about 28°F in polar regions to 80°F in equatorial regions. The bottom water of the oceans is always cold, the temperature being about 34°F.

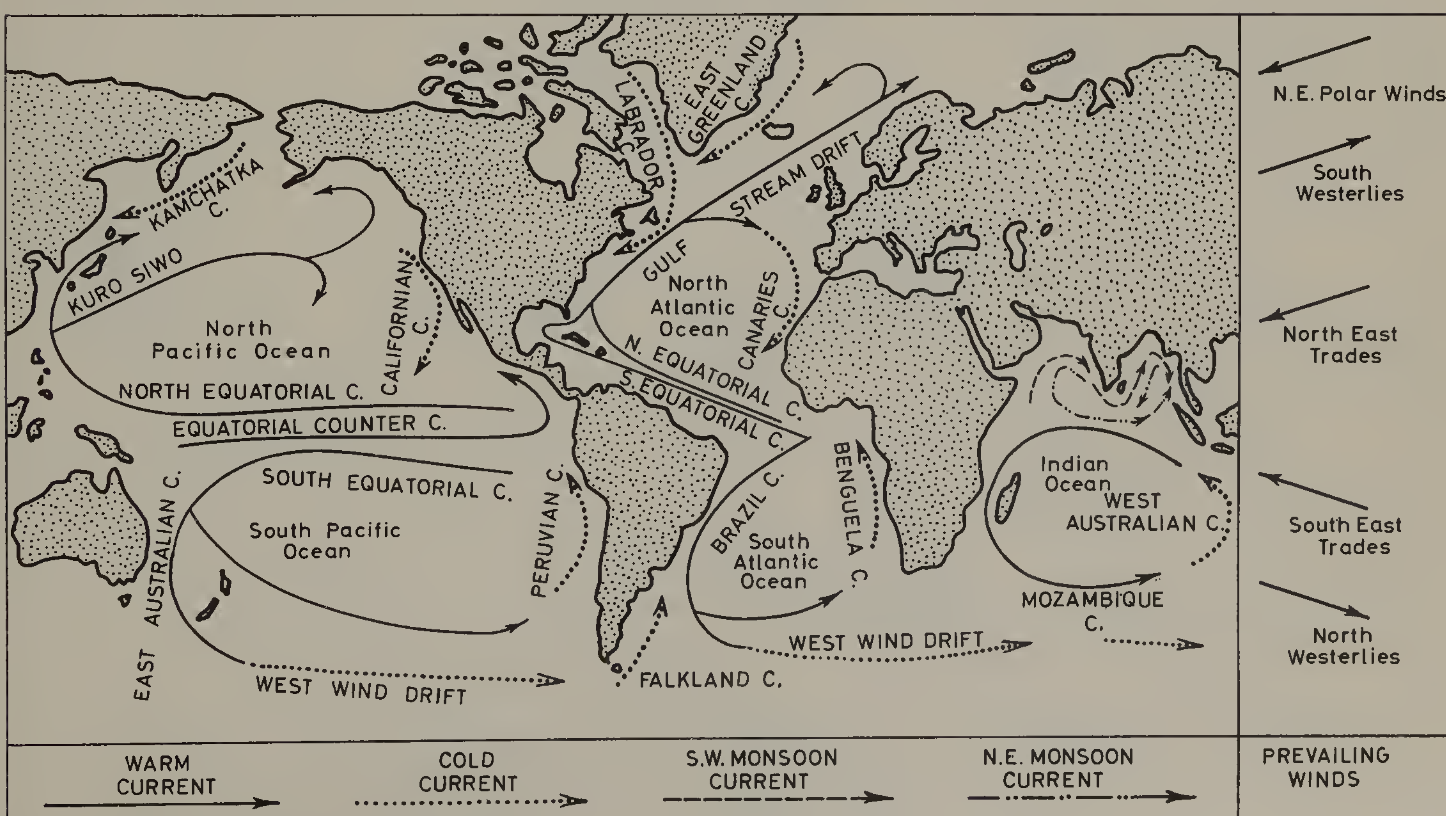
Water Movements in the Oceans

There are two types of movement:

1. *Horizontal*, i.e. ocean currents
2. *Vertical*, i.e. the rising of bottom water and the sinking of surface water.

These movements result from the combined action of:

1. *Density* (particularly important in vertical movements)
2. *Winds* (particularly important in horizontal movements).

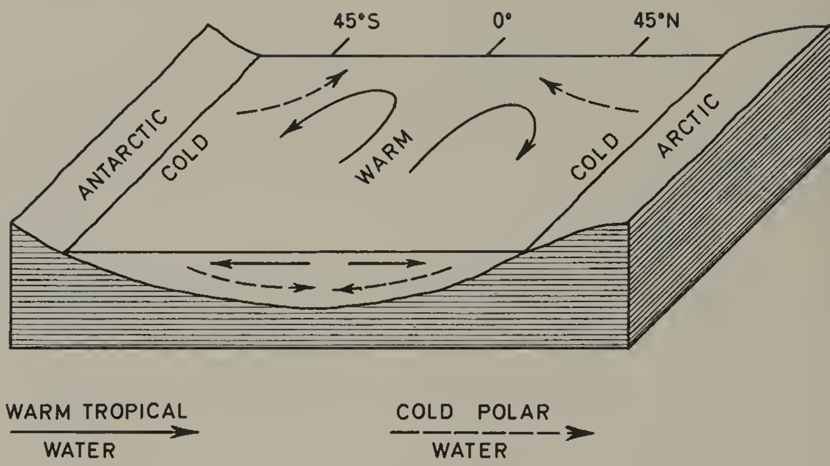


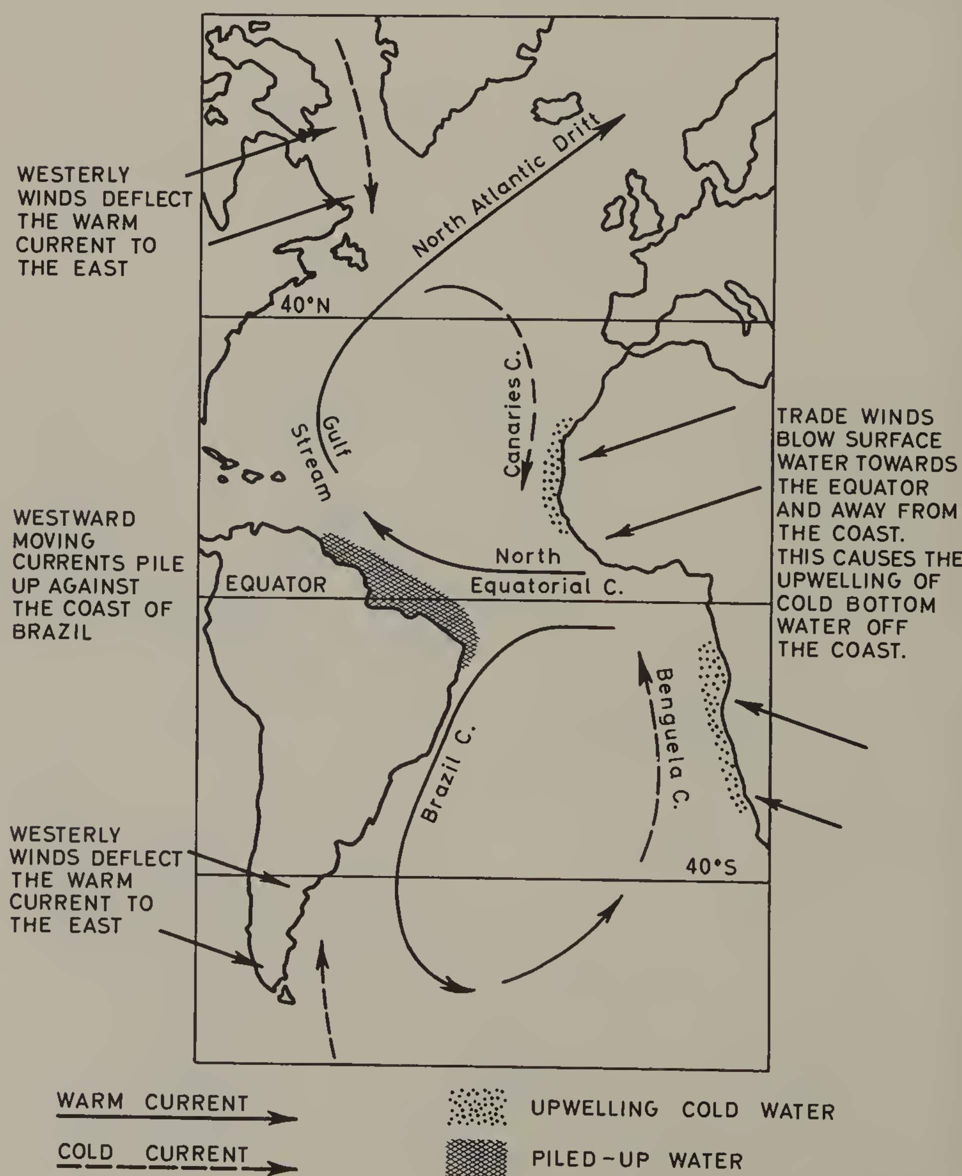
Ocean Currents of the World

The density of sea water depends upon the temperature and the amount of salt in the water. It falls when water is heated, as in the tropics; when there is a large inflow of fresh water, as in the Baltic (brought by rivers), and in the polar seas (from melting ice). It rises when evaporation is high and rainfall is low, as in the Red Sea; when water is cooled, as in the polar seas, and when water freezes (salts remain in the sub-surface water which does not freeze) as in the polar seas.

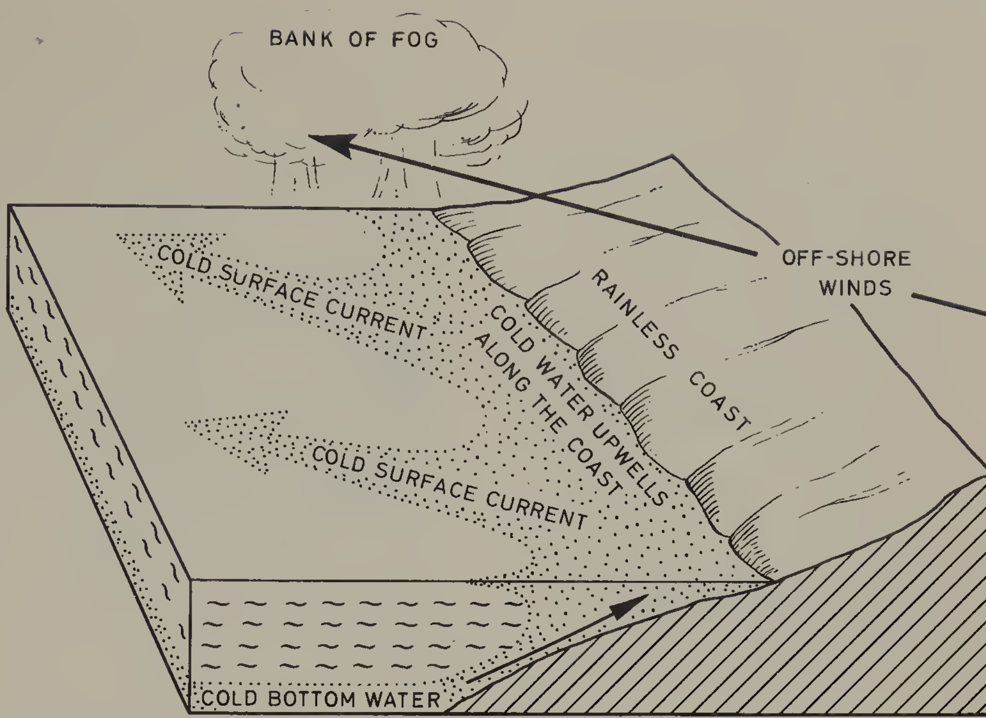
Ocean Currents

The top diagram shows a general drift of tropical water towards the poles and a return flow of polar water towards the equator. The polar flow begins as a surface current but slowly it sinks to the ocean bottom. The winds greatly modify this simple pattern: indeed, ocean currents closely resemble prevailing winds in their direction and position. Earth rotation and the shapes of the continents also influence the direction of currents. Study the bottom diagram which shows the general pattern of currents for the Atlantic Ocean. Notice how water is piled up along the Brazilian Coast, and how off-shore trade winds cause cold water to upwell along the west coast of Africa. This water forms the Canaries and Benguela Currents. The Californian and Humboldt Currents along the west coast of the Americas are formed in a similar way.

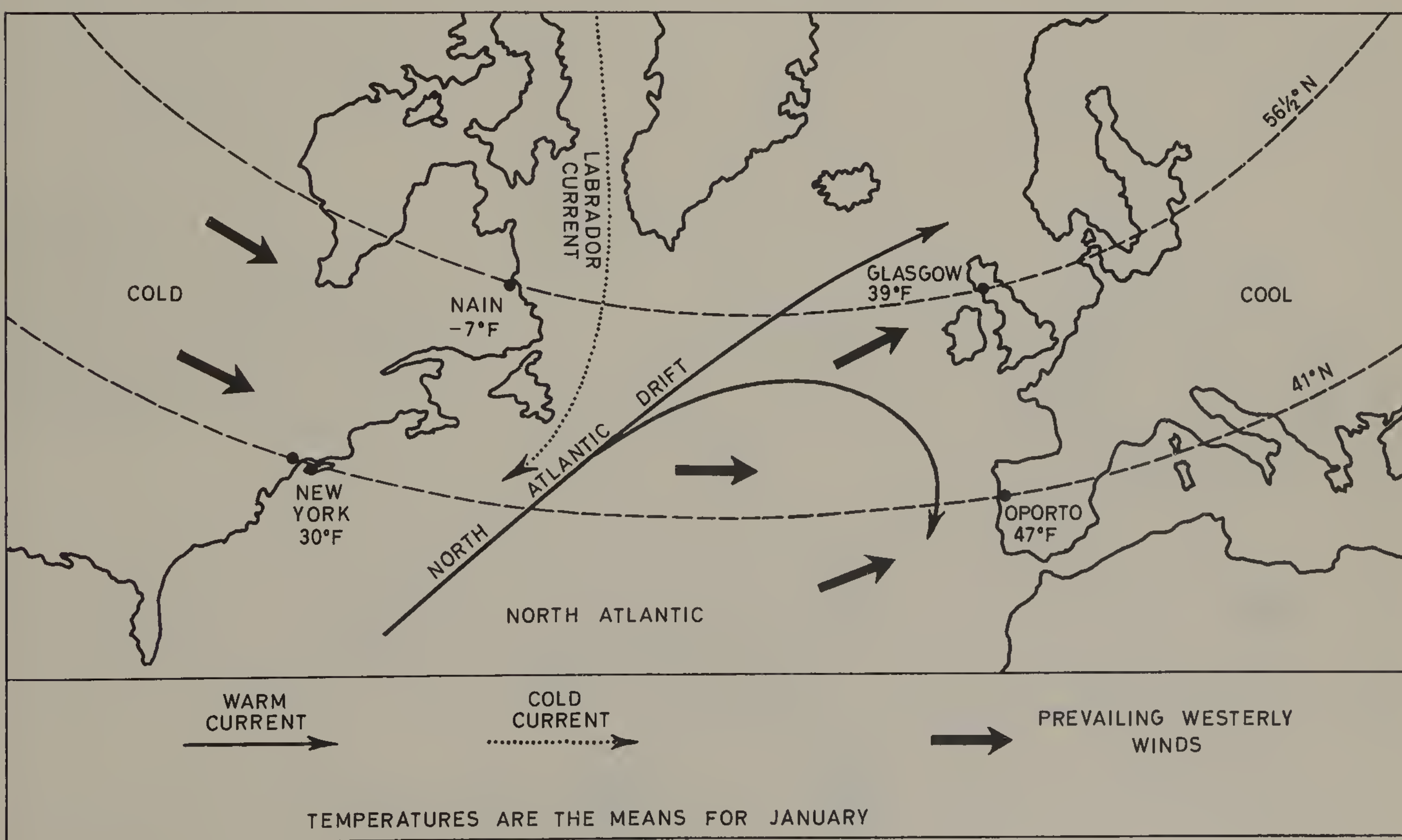




The diagram on the right indicates in greater detail how this type of cool current develops. These four currents have a cooling effect on the climates of coastal regions. Warm, moist air moving towards the coast is cooled as it passes over the cool currents and some of its moisture is condensed. Banks of mist develop along the coast. The air enters the coastal regions but there is no rain because the air is now drier. Also it is hot over the land and the air heats up and absorbs, rather than gives out moisture. Coastal mists are very common along the coast of Chile.



Ocean Currents can also Influence Climate

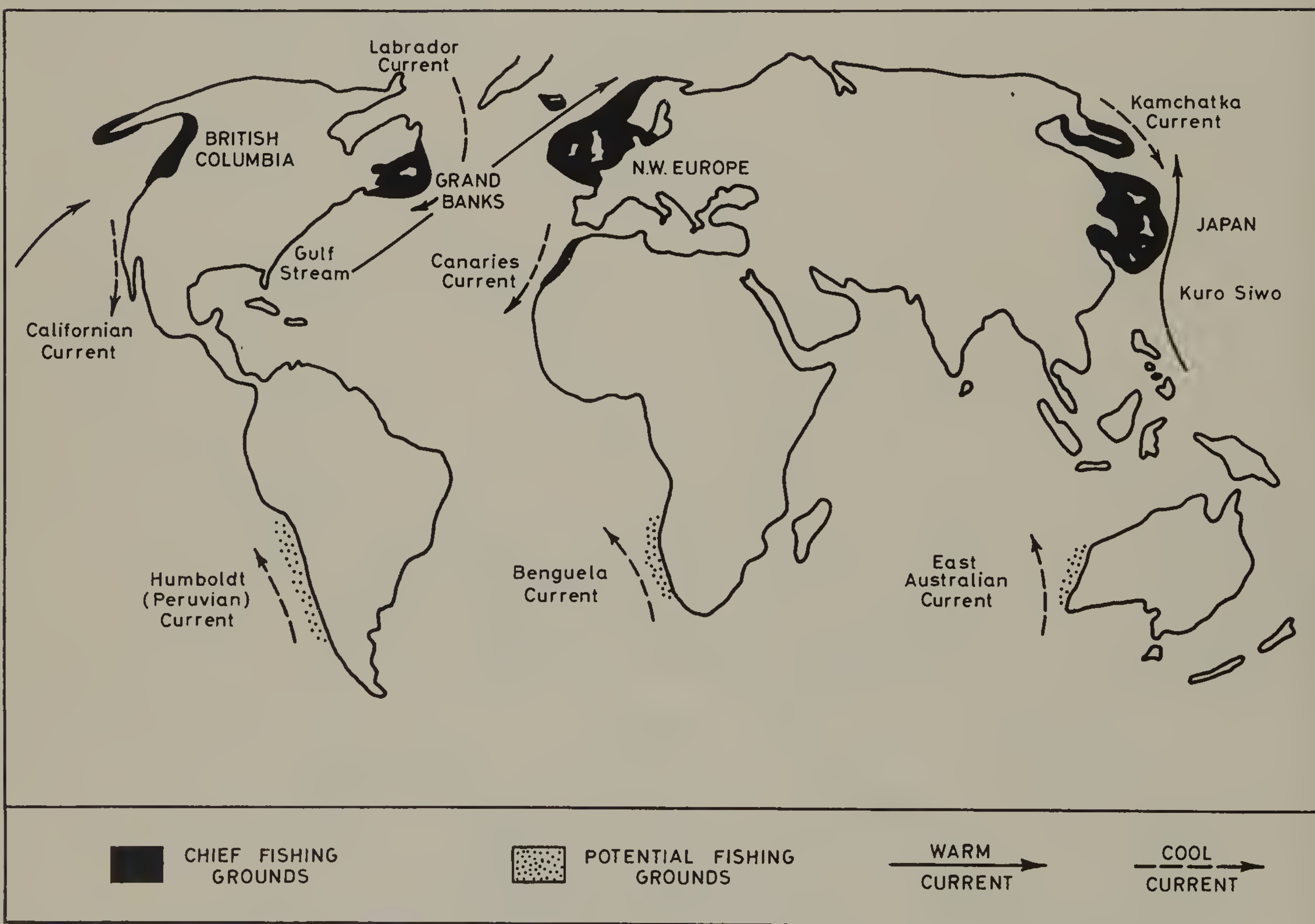


The Importance of the Oceans to Man

1 Oceans permit countries and regions to trade with one another. Goods can be moved in very large quantities by ships more cheaply than by any other means.

2 Some land margins would have colder winters if there were no warm currents in the nearby oceans. This would have an adverse effect upon such activities as agriculture.

3 The oceans contain a valuable source of food. The map shows the chief fishing grounds of the world. Notice that these occur in the continental shelf regions where cold and warm currents meet. Many fish feed on small green marine plants called plankton. These plants require nitrates and phosphates, sunlight and well-aerated water. Cold currents are rich in nitrates and phosphates, and epi-continental seas permit sunlight to reach almost to the bottom. The meeting of cold and warm currents causes the water to become well aerated. It is understandable therefore why the areas shaded black form the richest fishing grounds in the world.



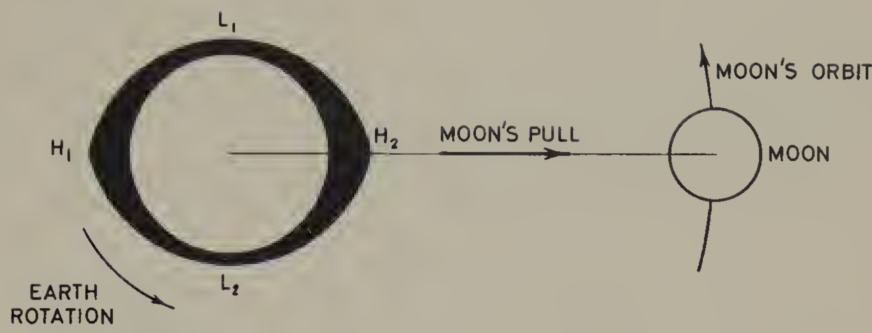
Fishing Grounds of the World

Tides

The tide is the alternate rise and fall of the surfaces of seas and oceans. It is caused mainly by the gravitational pull of the moon and to a lesser extent by that of the sun.

The Influence of the Moon

1 Water at H_2 is 'pulled' towards the moon more than the earth—therefore water piles up at H_2 forming a high tide.
2 The earth is 'pulled' towards the moon more than the water at H_1—therefore water piles up at H_1 forming a high tide.
3 The moon's 'pull' causes water to be drawn from L_1 and L_2—therefore there are low tides there.
4 The rotation of the earth results in every meridian coming into the positions of two high tides and two low tides very nearly every 24 hours. The moon travels in its orbit in the same direction as the earth is rotating and in consequence it takes about 24 hours 52 minutes, or one lunar day, for the sequence of two high and two low tides to be completed.



Spring and Neap Tides

At New Moon and Full Moon the sun, earth and moon are in a straight line and the combined 'pull' of the sun and moon results in very high tides and equally low tides. These are called *spring tides*.

SPRING TIDE AT NEW MOON

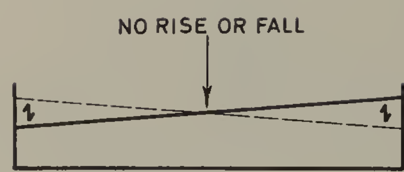
SPRING TIDE AT FULL MOON

At Half Moon the 'pull' of the sun is at right angles to that of the moon and hence the tides are neither as high nor as low as the spring tides. The range of the tide, i.e. the difference between high and low tide, is fairly small. These tides are called *neap tides.*

It is during Full Moon, New Moon and Half Moon that the influence of the sun is best seen.

Tides and Waves

At one time it was believed that the tide-producing forces resulted in the formation of two large tidal waves (H_1 and H_2 in the diagram at the top of page 107) which progressively moved westward across the Southern Ocean. From these, minor tidal waves were sent out into the Pacific, Indian and Atlantic Oceans and their neighbouring seas. The two tidal waves were separated by low water (L_1 and L_2). Observations on tidal waves in different parts of the world show that this explanation can no longer be accepted. The present theory maintains that the oceans can be divided into zones in each of which the tide-producing forces cause the surface of the water to oscillate. This means that the water will rock bodily, rising and falling around the edges of the water body whilst near the centre there will be practically no rise or fall in water level (diagram on the right).



Bores

When a tidal wave enters an estuary the wave increases in height as the estuary becomes increasingly shallow and narrow. Ultimately, the wave breaks and forms a wall of foaming water which often surges forward at several miles per hour. This usually happens when the tidal wave meets a river. Bores occur on these rivers: Hooghly, Tsien-tang-kiang (N. China) and Amazon.

Chapter 5 Lakes

A lake can be defined as a hollow in the earth's surface in which water collects. Some lakes are of great size and are called seas, e.g. Caspian, Dead and Aral Seas. Although most lakes are permanent, some contain water in the wet season only. Lakes in basins of inland drainage (which are usually semi-arid) may contain water for a few months only out of a period of several years.

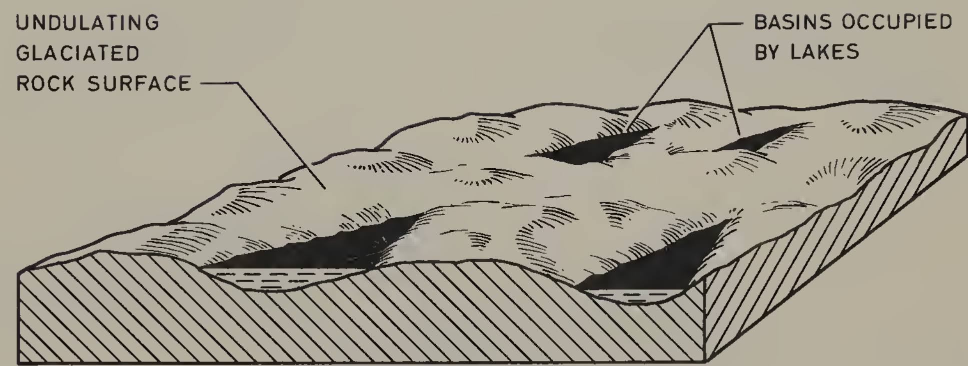
Classification of Lakes (according to origin)

The majority of lakes have been formed by the action of glaciers and ice sheets. The rest have been formed by wind or river action, or earth movements or vulcanicity.

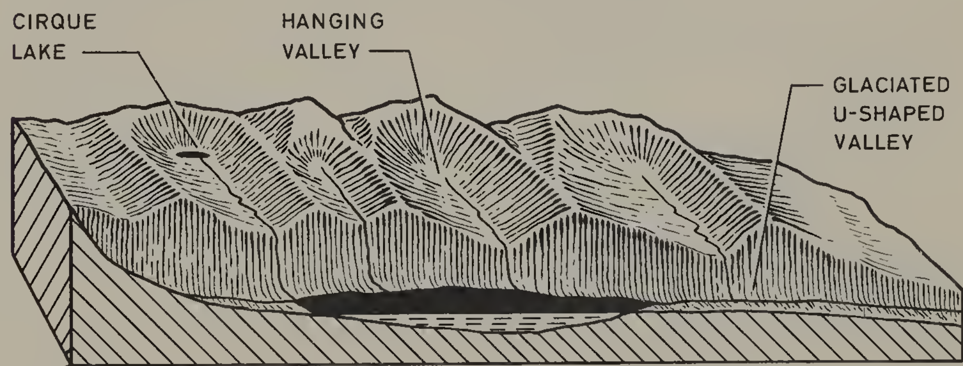
Lakes Produced by Erosion

I By Glaciers

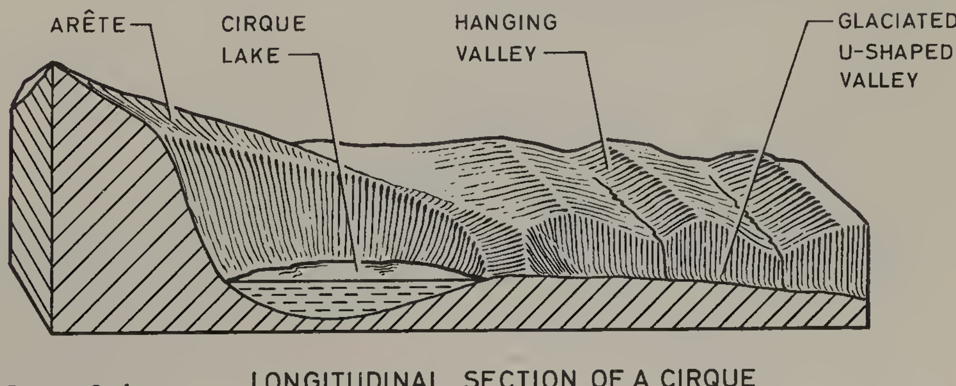
Both valley glaciers and ice sheets can gouge out hollows and troughs on the earth's surface. These may later fill with water to form lakes. Many cirques and glaciated valleys contain lakes which occupy rock hollows (sometimes moraines are present which also partly dam the lakes). The ancient shields of North America and Scandinavia contain tens of thousands of lakes of the type shown in the top diagram. The Laurentian Shield of Canada and the Lake Plateau of Finland contain more rock basin lakes than any other part of the world.



Rock Basin Lake



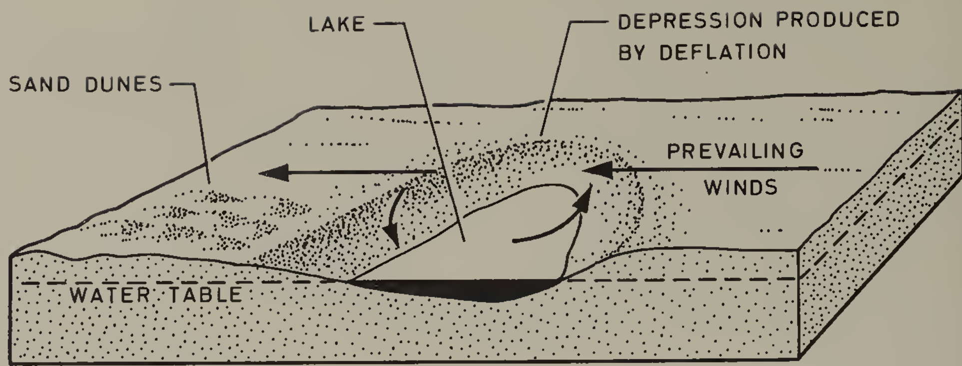
Glaciated Valley Trough Lake



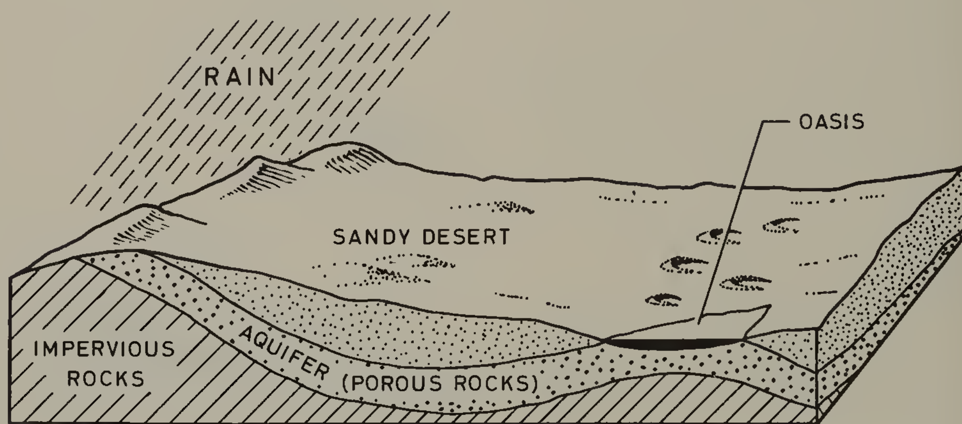
Cirque Lake

II By Wind

Wind deflation sometimes produces extensive depressions in arid regions like the deserts of the Southern Continents and Central Asia. If the depression is excavated below the water table then a lake will develop (top diagram). This diagram shows that it is the action of eddy currents which scoop out the loose sand which is then blown away and deposited as dunes. The lakes of these depressions are not always true lakes for they may be nothing more than muddy swamps. The *Qattara Depression* in Egypt is a good example of a depression produced by wind deflation. More permanent types of lakes called oases develop when an aquifer is exposed at the desert surface (middle diagram).



Desert Depression Lake



Oasis

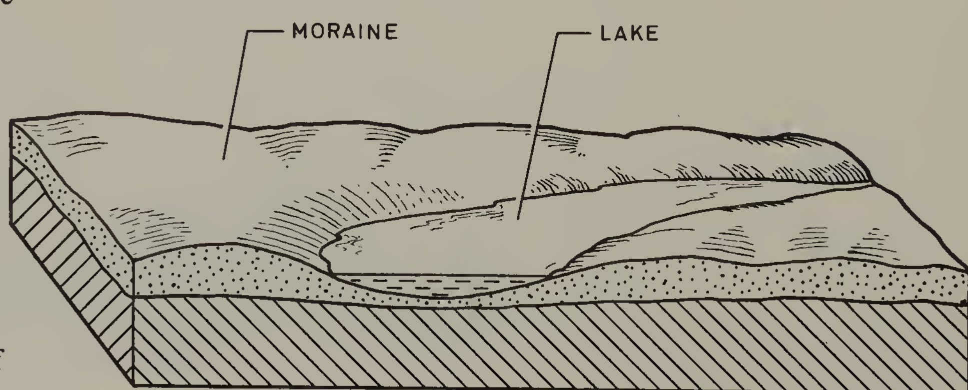
Lakes Produced by Deposition

I By Rivers

Rivers meandering across a flood plain frequently produce cut-offs which later develop into ox-bow lakes (see page 59). Spits and bars which develop along some coasts, especially delta coasts, give rise to lagoons. All the world-famous deltas contain lagoons or delta lakes, e.g. *Lake Manzala* in the Nile Delta (see figure on page 62).

II By Glaciers

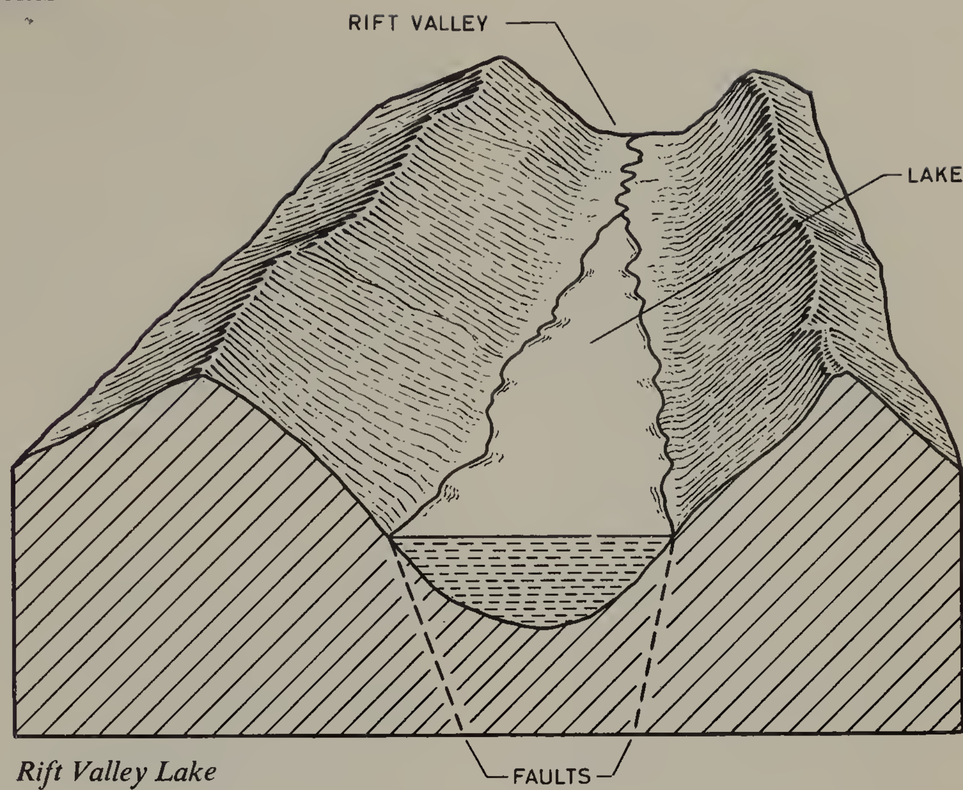
Many lakes in a glaciated region are caused by the damming action of moraine. Terminal moraines sometimes block valleys and cause lakes to form (bottom diagram). *Lake Garda* (Italy) and the lakes of the *Lake District* (England) are examples of such lakes.



Moraine-dammed Lake

Lakes Produced by Earth Movements

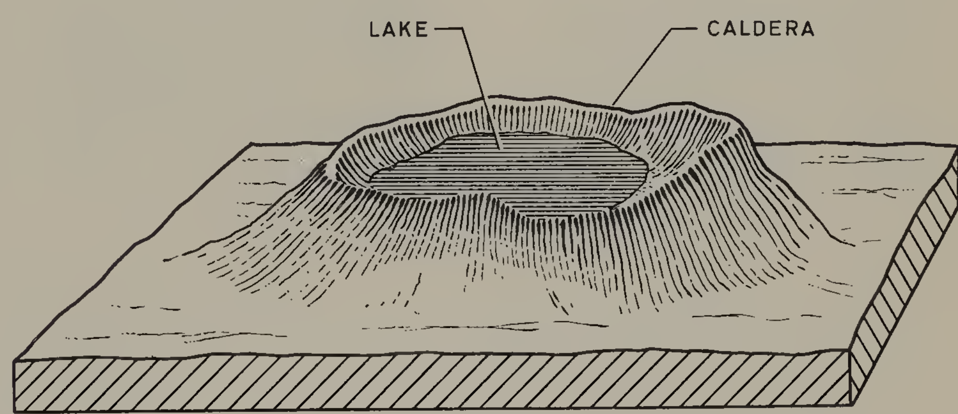
Sagging and faulting in the earth's crust produce depressions which may later contain lakes. Most rift valleys contain lakes (top diagram), and some of the best examples of such lakes are *Lakes Nyasa, Tanganyika* (in Africa), the *Dead Sea*, and *Lake Baikal* (U.S.S.R.). Basin landscapes produced by sagging in the earth's crust are often regions of inland drainage and some contain lakes, many of which, however, are either seasonal or appear for a few months only every 4 or 5 years. All these lakes are extremely salty. Examples include the Great Salt Lake of U.S.A., Lake Chad in West Africa and Lake Eyre in Australia.



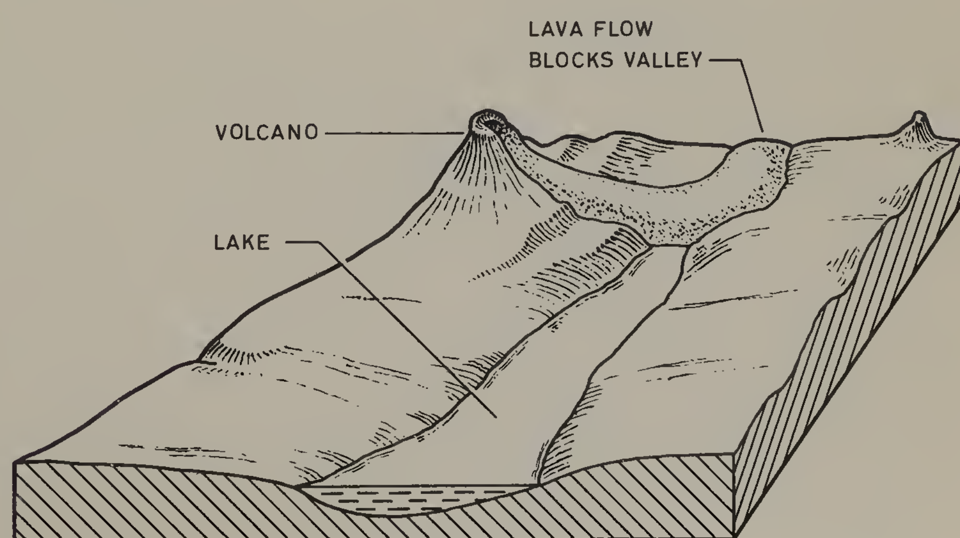
Rift Valley Lake

Lakes Produced by Vulcanicity

The craters of extinct volcanoes often contain lakes. The largest of these is *Lake Toba* (area 750 sq. mi.) in Northern Sumatra. This lake occupies a caldera. The lava-flows from some volcanoes block river valleys and cause lakes to form. The *Sea of Galilee* has been formed by the blocking of the Jordan Valley by a lava-flow.



Crater Lake



Lava-dammed Lake

The Value of Lakes to Man

1 A lake helps to regulate the flow of a river in this manner:
  (i) When rainfall is heavy the lake absorbs the rainfall and prevents or reduces flooding lower down the valley, e.g. Yangtze-kiang.
  (ii) In times of drought water in the lake helps to maintain an even water flow in the river. The level of a river without a lake often falls appreciably during the dry season.

2 The water of some lakes can be used for developing hydro-electric power, e.g. at the Niagara Falls (using the water of Lake Erie).

3 Some lakes afford important means of transport, e.g. the Great Lakes of North America.

4 Many lakes contain fish, and some have a sufficiently large fish population to make them valuable as a source of food, e.g. Tonle Sap in Cambodia and the Caspian Sea in U.S.S.R.

5 Lakes are sometimes used as a source of water for neighbouring towns, e.g. the lakes of the Lake District in England.

6 Some lakes supply water to irrigation projects, e.g. Lake Tana in Ethiopia.

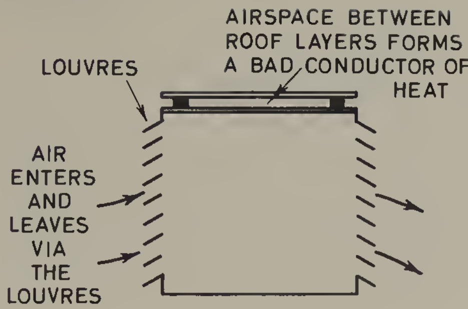
7 Lakes, especially those in mountainous regions, attract many people and in some instances they give rise to important tourist activities, e.g. the Swiss and Italian Alpine Lakes and the English Lakes.

8 Extensive lakes in temperate latitudes have a moderating influence on the climate of nearby regions. In winter the lakes have a warming influence (release of stored-up summer heat), and in summer they have a cooling influence. Lakes also supply water vapour to winds passing over them and thus influence the rainfall pattern of nearby regions. This is well shown in the Lake Peninsula of Ontario which is almost surrounded by the Great Lakes.

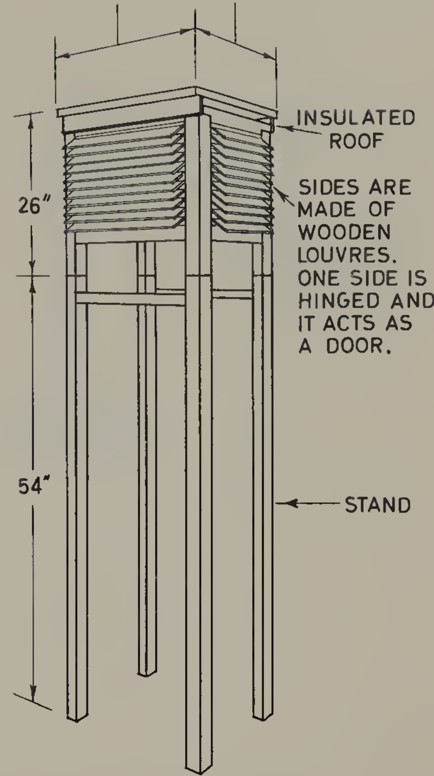
Chapter 6 Weather

When we say it is hot, or wet, or cloudy, we are saying something about the weather. Weather refers to the state of the atmosphere: its temperature, pressure and humidity for a place for a short period of time. If we want to find out what the weather is like we must examine:

1 temperature 2 humidity
3 pressure 4 rainfall
5 wind direction and strength
6 the cloud cover 7 sunshine



SECTION VIEW



STEVENSON SCREEN

Measuring and Recording Weather Elements

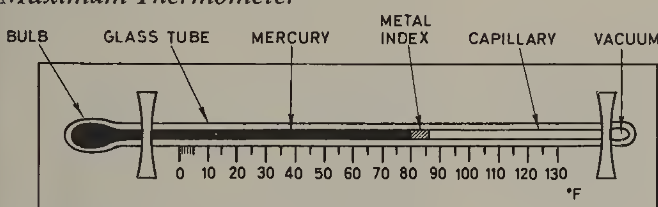
A weather station is a place where all the elements of weather are measured and recorded. Each station has a Stevenson Screen (diagrams top and right) which contains four thermometers which are hung from a frame in the centre of the screen. They are:

1 Maximum thermometer
2 Minimum thermometer
3 Wet bulb thermometer
4 Dry bulb thermometer

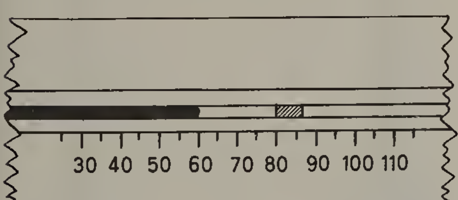
The screen is so built that the shade temperature of the air can be measured. It is a wooden box whose four sides are louvred to allow free entry of air. The roof is made of double boarding to prevent the sun's heat from reaching the inside of the screen, and insolation is further improved by painting the outside white. It is placed on a stand, four to five feet above ground level.

To measure maximum and minimum temperature

Maximum Thermometer



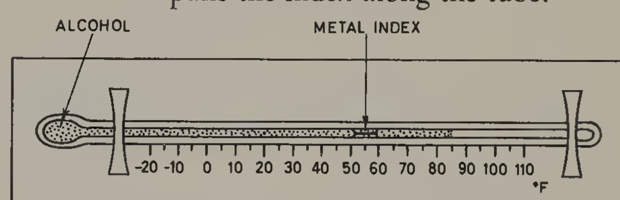
When the temperature rises the mercury expands and pushes the index along the tube.



When the temperature falls the mercury contracts and the index remains behind. The maximum temperature is obtained by reading the scale at the end of the index which was in contact with the mercury. In the diagram this is 80°F. The index is then drawn back to the mercury by a magnet.

Minimum Thermometer

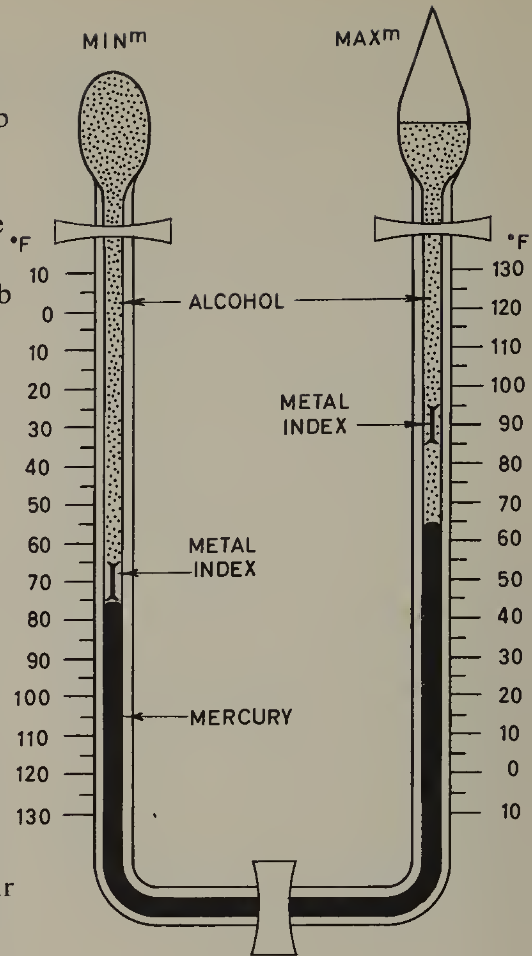
When the temperature falls the alcohol contracts and its meniscus pulls the index along the tube.



When the temperature rises the alcohol expands. The index does not move but remains in the position to which it was pulled. The minimum temperature is obtained by reading the scale at the end of the index which is nearer the meniscus. In the diagram this is 60°F. By raising the bulb of the thermometer the index is returned to the meniscus.

Six's Thermometer

This thermometer can also be used for measuring maximum and minimum temperatures. When the temperature rises the mercury in the left-hand limb expands and pushes the mercury down this limb and up the right-hand limb. The alcohol in this limb also heats up and part of it is vaporised and occupies the space in the bulb. The maximum temperature is read from the scale on the right-hand limb. When the temperature falls the alcohol in the left-hand limb contracts and some of the alcohol vapour in the conical bulb liquefies. This causes the mercury to flow in the reverse direction. The minimum temperature is read from the scale on the left-hand limb. Note this scale is reversed.



Humidity of the Air

No air is absolutely dry although some air, such as that over tropical deserts, contains very little water vapour. Humidity refers to the amount of water vapour in the air, but it is more important to know the relationship between the actual amount of vapour in the air and the amount of vapour the air could hold at that particular temperature. This amount is called the *Relative Humidity* (R.H.). Thus if the R.H. is 80 per cent at a temperature of 85°F, then the air is holding eight-tenths of the water vapour it could hold at that temperature. When air can hold no more vapour we say the air is saturated and its R.H. is 100 per cent. Now the amount of vapour air can hold is dependent upon its temperature. When this rises the air is able to hold more vapour, and when it falls it cannot hold as much. When the temperature falls it may well be that the air contains more vapour than it can hold. The excess vapour then condenses, i.e. turns into water droplets which form either clouds, rain, mist or fog.

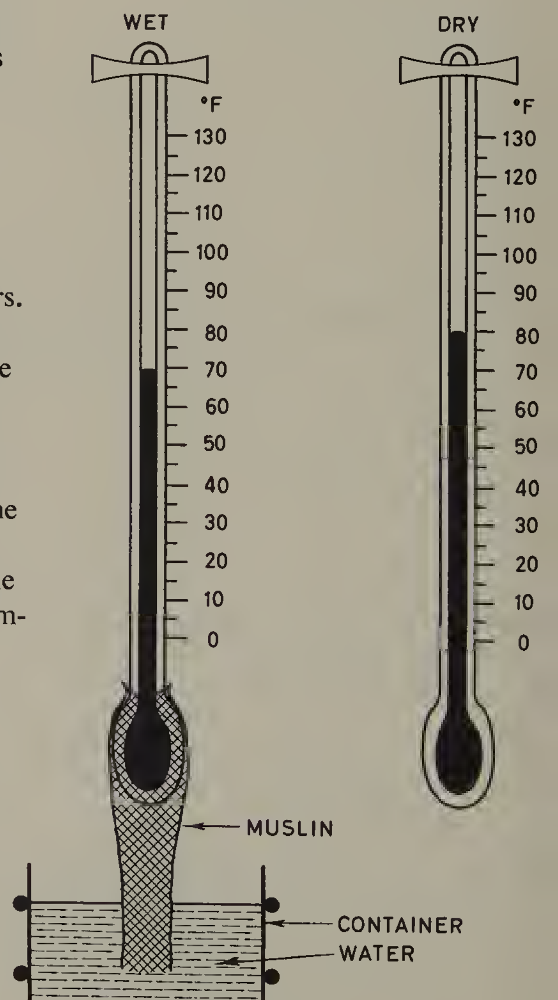
Measurement of Humidity

The hygrometer shown on the right consists of two ordinary thermometers. The bulb of one is wrapped in a piece of muslin which dips into a container of water. This thermometer is called the wet bulb thermometer. The other is called the dry bulb thermometer. When the air is not saturated, water evaporates from the muslin and this cools the wet bulb and causes the mercury to contract. The dry bulb thermometer is not affected in the same way, and so the two thermometers show different readings. When the air is saturated, there is no evaporation and hence no cooling. The two thermometers therefore show the same reading. The difference between the two readings is, therefore, an indication of the humidity of the air. Remember these statements:

Thermometer readings

1 No difference — air is saturated.
2 Small difference — humidity is high.
3 Large difference — humidity is low.

Note The actual value of relative humidity is obtained by applying the temperature readings to a book of tables.

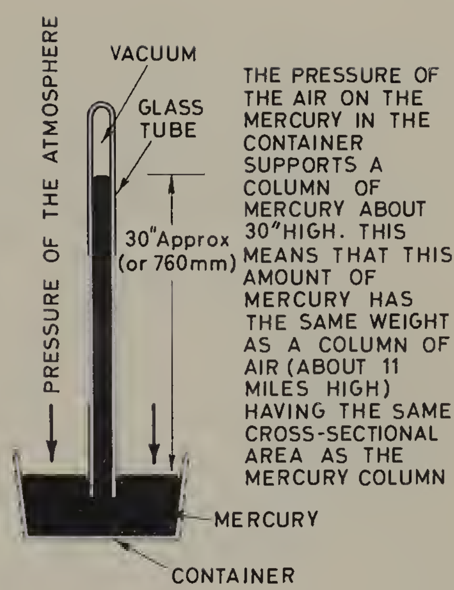


Simple Hygrometer

Atmospheric Pressure and its Measurement

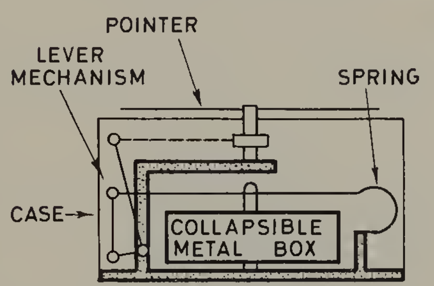
Air has weight and thus it exerts a pressure on the earth's surface. At sea level this is 14.7 lb per sq. in. Pressure varies with both temperature and altitude, and the instrument which measures pressure is called a barometer. There are two types of barometer: 1 Mercury barometer 2 Aneroid barometer

Mercury Barometer
Although this is a large and cumbersome instrument, it is very accurate and is used in many weather stations. Atmospheric pressure is read either in inches or in millibars.



Aneroid Barometer
The heart of this instrument consists of a small metal box which contains very little air. The top of this bends slightly under the influence of any change in atmospheric pressure. The movement of the box top is conveyed by a system of levers to a pointer which moves across a graduated scale. When the pressure rises the box top bends in and when the pressure falls the spring pushes the box top outwards.

Aneroid Barometer (sectional view)

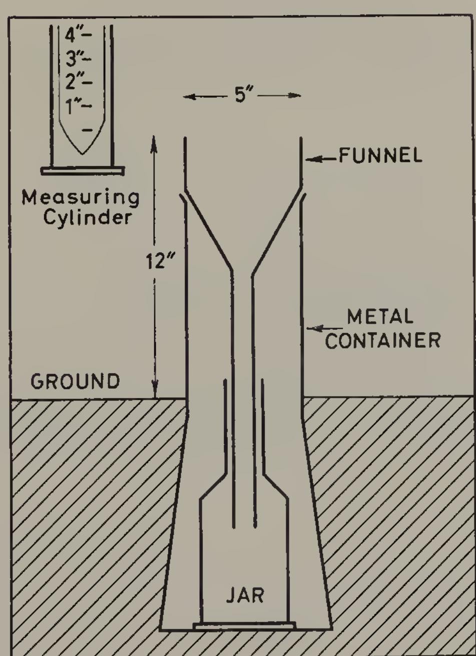


The Measurement of Rainfall

All weather stations have a rain gauge. Rain falling in the funnel trickles into the jar below and at the end of a 24-hour period this is poured into a graduated measuring cylinder. The graduation of the cylinder is such that the reading obtained is the depth of rain that has fallen over an area equivalent to that of the top of the funnel. Rainfall is measured in inches, and the cylinder is tapered at the bottom (see inset) to enable very small amounts to be measured accurately.

Position of the Rain Gauge
It must be placed in an open space so that no run-off from buildings or trees, etc., enters the funnel. It must also be sunk into the ground so that about 12 inches of it sticks up above ground level. This prevents rain from splashing into it from the ground, and also prevents the sun's rays from causing excessive evaporation of the water already collected in the jar.

Rain Gauge



Clouds

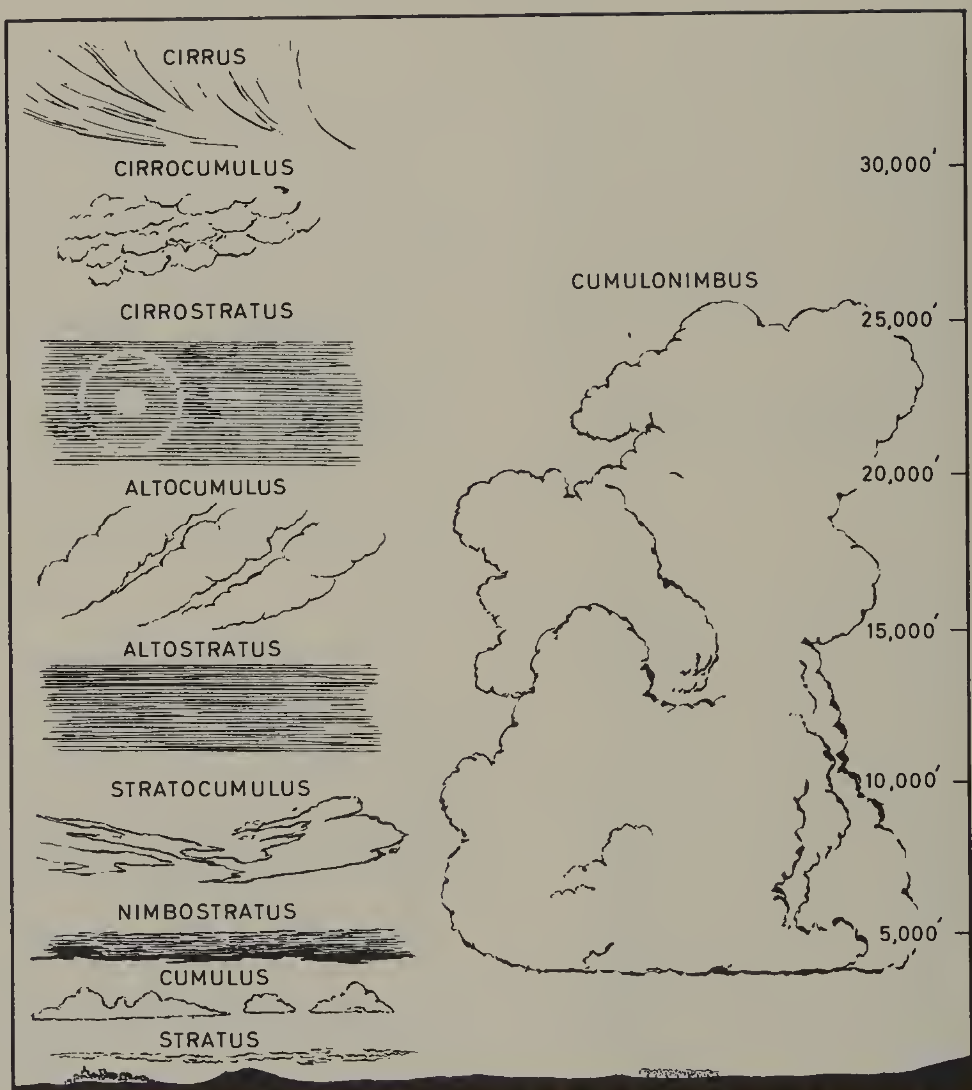
When air is cooled some of its water vapour may condense into tiny droplets of water. The temperature at which the change takes place is called the *dew-point temperature*. Clouds are made of water droplets, and so are mists and fogs which are really low-level clouds. Clouds are named partly according to their appearance and partly according to their altitude. The ten main types of clouds are shown in the diagram.

Cloud Types

Below 10,000′
Stratocumulus: low rolling cloud.
Stratus: fog-like cloud near ground.
Nimbostratus: dark grey layered cloud.

10,000′ to 20,000′
Altostratus: a watery-looking cloud.
Altocumulus: slightly globular with a flattened base.

Over 20,000′
Cirrostratus: thin, sheet-like cloud.
Cirrocumulus: this cloud forms ripples.
Cirrus: a wispy cloud.
Cumulus and cumulonimbus clouds: these occur at different altitudes. Cumulus clouds have flat bases, rounded tops and are usually white or grey. Cumulonimbus clouds have a more ragged base and they rise up to very great heights. The tops of these clouds usually bend over like a mushroom. Such clouds are very common in the humid tropics and they are associated with thunder storms.



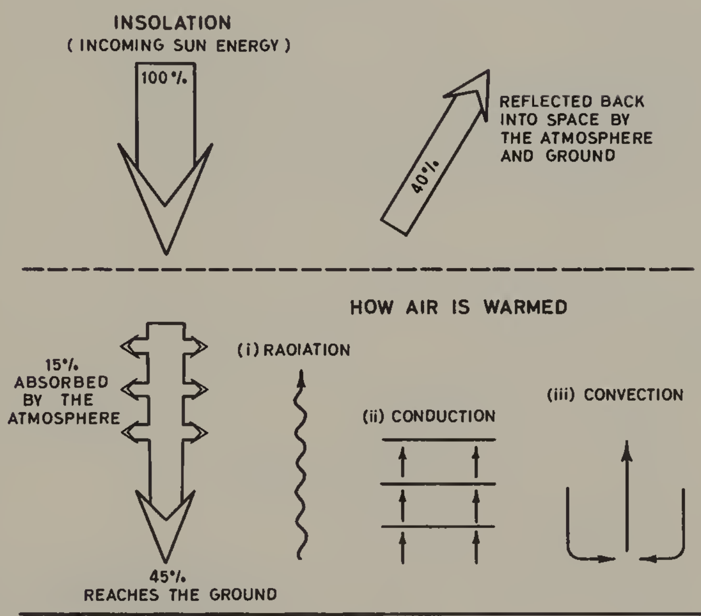
Chapter 7 Climate

When we say that Malaya is hot and wet all the year, or that Central Chile has hot dry summers and warm mild winters, we are in fact saying something about the state of the atmosphere over a long period of time. What we are really describing is the average state of the atmosphere, and such descriptions refer to the state of the climate. Before we make a study of the main types of climate, we must examine temperature, pressure and rainfall, etc., and find out what it is that causes these to vary from region to region. We must also know how to find the average state of these elements.

Temperature

Insolation and how Air is Heated

The sun's energy is called insolation and this is turned into heat at the earth's surface. Only about 45 per cent of the incoming insolation reaches the surface. The heat generated at the surface warms the air by *radiation* (heat waves sent out by the earth's surface), *conduction* (passing of heat by contact), and *convection* (passing of heat by air currents).



Heating and Cooling of Land and Water Surfaces

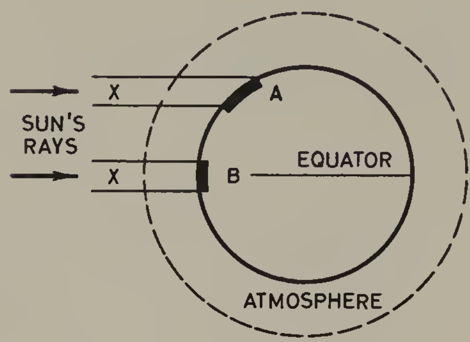
It takes over five times as much heat to raise the temperature by 1°F for a given volume of water as it does for the same volume of land. This is what the common statement 'land heats up more quickly than water' implies. The reverse of this, i.e. 'land cools more quickly than water', is equally true. In N.W. Europe this condition causes the coastal regions to be warmed by the seas in winter and cooled by them in summer.

Now water is fairly transparent and hence the sun's rays penetrate to considerable depths. Therefore, the heat which develops is more widely distributed than it is on land. Also water movements in the seas cause the heat to be further distributed. All this means that a much greater volume of sea is heated than is the case with land.

Factors Influencing Temperature
The temperature of a place is dependent upon some or all of these factors:

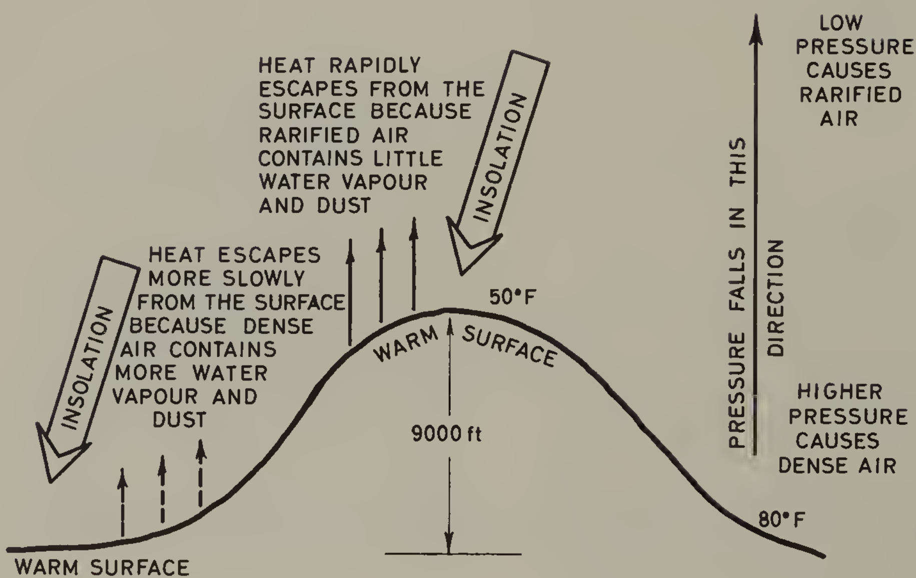
1 Latitude
2 Altitude
3 Ocean currents
4 Distance from the sea
5 Winds
6 Aspect
7 Cloud cover

Latitude
The altitude of the midday sun is always high in the tropics and hence temperatures are always high. Outside the tropics the altitude is lower and temperatures are correspondingly lower. In general temperatures decrease from the equator to the poles. The diagram explains this. Bands marked X contain equal amounts of sun energy, but, because area B is smaller than area A, the temperature at B will be higher than that at A. Notice also that the sun's rays at A have passed through a greater thickness of atmosphere than have those at B, and hence more sun energy arrives at B than at A.



Altitude
We have already seen that the sun's rays heat the earth's surface which then passes on its heat to the air. Water vapour and dust in the air prevent this heat from rapidly escaping back into space, but at high altitudes, e.g. on the top of a high mountain, air is rarefied and it contains very little vapour or dust. The heat from the earth's surface therefore rapidly escapes and the air remains cold (see diagram). In tropical arid regions such as hot deserts the almost complete absence of water vapour results in the earth's surface becoming intensely hot in the day. During the night most of this heat rapidly passes back into space with the result that night temperatures drop appreciably. Such regions have a large *diurnal* (daily) range of temperature.

In general temperature falls off by 1°F for every 300′ ascent. Hence if the temperature at the bottom of a 9,000′ mountain is 80°F, then the temperature at the top is 50°F (see diagram).

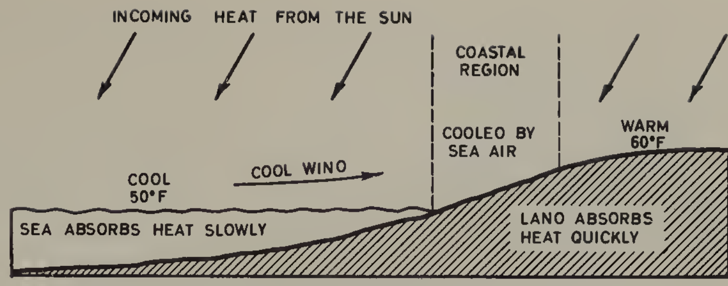


Ocean Currents

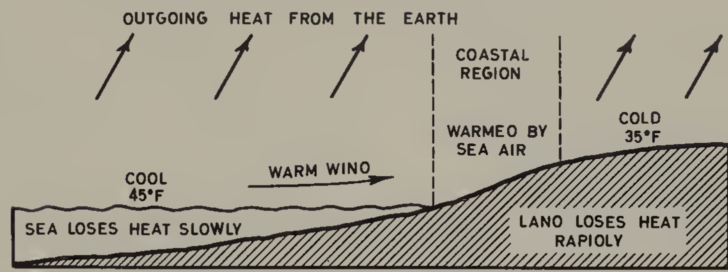
Warm and cold currents often raise or lower the temperatures of land surfaces if the winds are on-shore.

(i) Warm currents moving polewards carry tropical warmth into the high latitudes, and this warming influence is very marked in latitudes 40° to 65° on the west sides of continents, especially along the seaboard of Western Europe (page 105). The warmth is conveyed to the land by the prevailing Westerly Winds. This action is almost entirely confined to the winter season. Between latitudes 0° and 40° on the eastern sides of continents warm currents raise coastal temperatures.
Note In tropical latitudes on-shore winds crossing warm currents do not raise the temperature of the air over the land because this is already high.

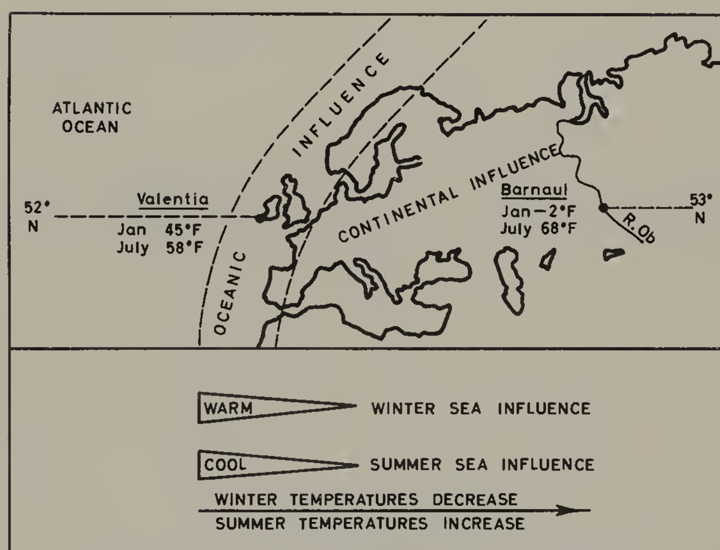
(ii) Cold currents have less effect upon temperatures because they usually lie under off-shore winds (page 104). There are exceptions, e.g. the coast of Labrador, when summer temperatures are lowered by on-shore winds which blow over the cold Labrador Current.



MID-SUMMER TEMPERATURE CONDITIONS IN A TEMPERATE LATITUDE (TEMPERATURES ARE APPROXIMATE)



MID-WINTER TEMPERATURE CONDITIONS IN A TEMPERATE LATITUDE (TEMPERATURES ARE APPROXIMATE)



Distance from the Sea

The sun's heat is absorbed and released more slowly by water than by land. This becomes very noticeable in temperate latitudes in the winter season when sea air is much warmer than land air. Hence on-shore winds bring warmth to coastal regions. This warming influence is confined to a narrow coastal belt because the sea air rapidly loses its heat to the colder land. Air temperatures decrease from the coast inland (middle diagram). In the summer season land surfaces are warmer than sea surfaces and the air over the sea is therefore warmer than that over the land. Therefore coastal regions are cooler than inland regions (bottom diagram).

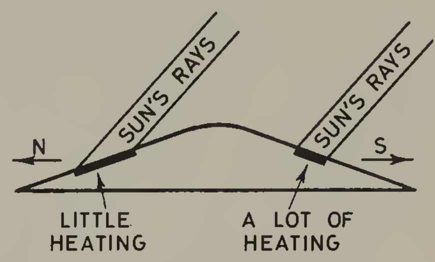
Climates whose temperatures are influenced greatly by the sea are called *maritime*, or *oceanic*, or *insular* climates. These occur in coastal regions which lie under prevailing on-shore winds. Climates whose temperatures are greatly influenced by remoteness from the sea are called *continental* climates. These occur in the hearts of temperate continents.

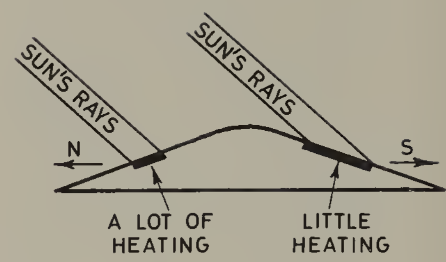
Winds

In temperate latitudes prevailing winds from the land lower the winter temperatures but raise the summer temperature. Prevailing winds from the sea raise the winter temperatures but lower the summer temperatures. In tropical latitudes on-shore winds modify the temperatures of coastal regions because they have blown over cooler ocean surfaces. *Local winds* (see page 133) sometimes produce rapid upward or downward temperature changes.

Aspect

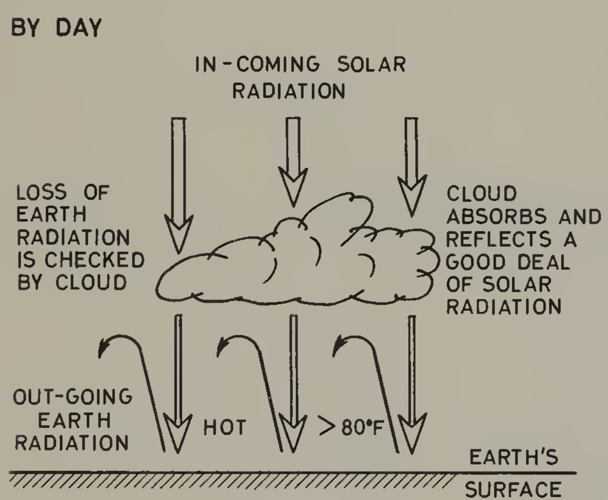
The influence of aspect on temperature is only noticeable in temperate latitudes. In the tropics, the midday sun is always high in the sky and aspect is of little significance. South-facing slopes are warmer than north-facing slopes in the northern hemisphere, whilst in the southern hemisphere the reverse is true (see diagrams on the right).

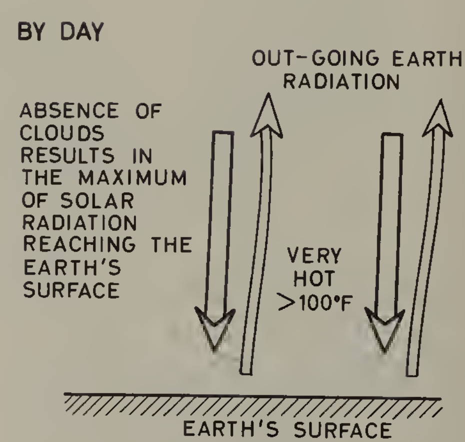


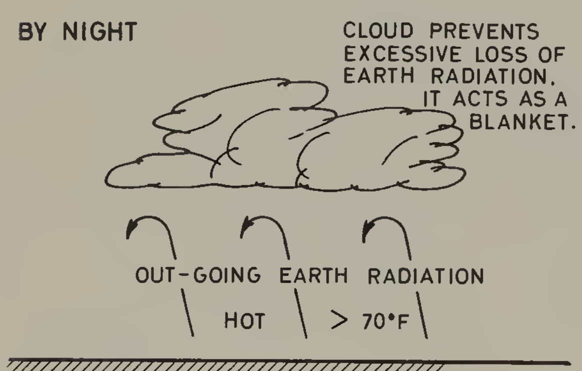


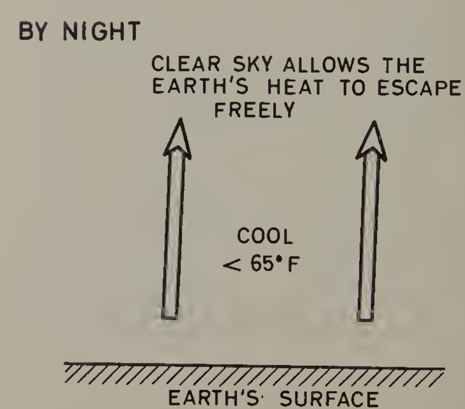
Cloud Cover

Clouds reduce the amount of solar radiation reaching the earth's surface and the amount of earth radiation leaving the earth's surface. When there are no clouds both types of radiation are at a maximum. The heavy cloud cover of the equatorial regions explains why the day temperatures rarely exceed 85°F and why the night temperatures are not much lower. In hot deserts the absence of clouds results in very high day temperatures (over 100°F) and much lower night temperatures (below 70°F).

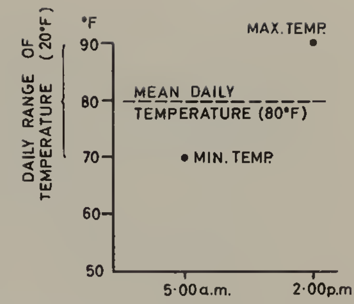








Temperature Readings and Recording



1 $\left(\dfrac{\text{Daily Max. Temp.} + \text{Daily Min. Temp.}}{2}\right)$ gives the MEAN DAILY TEMPERATURE.

See diag. Mean Daily Temperature is 80°F $\left(\dfrac{90° + 70°}{2}\right)$

2 (Daily Max. Temp. − Daily Min. Temp.) gives the DAILY RANGE OF TEMPERATURE.

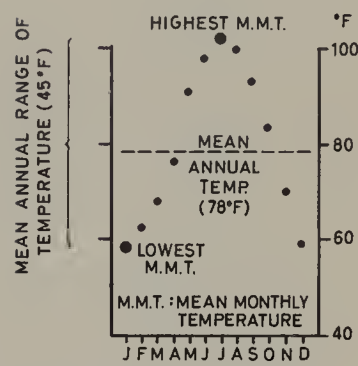
See diag. Daily Range of Temperature is 20°F (90°–70°).

3 $\left(\dfrac{\text{Sum of Mean Daily Temps. for 1 month}}{\text{Number of days in month}}\right)$ gives the MEAN MONTHLY TEMPERATURE.

4 $\left(\dfrac{\text{Sum of Mean Monthly Temps. for 1 year}}{12}\right)$ gives the MEAN ANNUAL TEMPERATURE.

See diag. Mean Annual Temperature is 78°F.

5 (Highest Mean Monthly Temp. − Lowest Mean Monthly Temp.) gives the MEAN ANNUAL RANGE OF TEMPERATURE. See diag. Mean Annual Range of Temperature is 45°F (100°–55°).



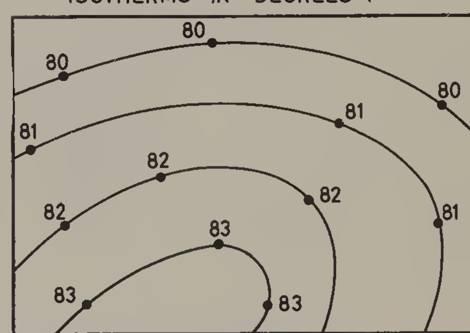
EL GOLEA–SAHARA DESERT

Temperature Graphs and Maps

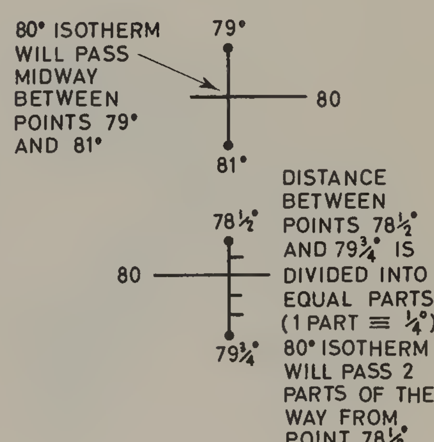
A Graph is used to show the temperature for *a place*. If the points in the right diagram above were joined by a smooth curve this would be a temperature graph.

A Map is used to show the temperatures for a *region*. The positions of all weather stations must first be plotted by dots on the map. The temperature for each station is then adjusted to what it would be if that station was at sea level. This is done by adding 1°F for every 300′ of height for the station. The adjusted temperature values are then written alongside the dots and all places having the same temperature are joined by a smooth line. Such a line is called an *isotherm*. The diagram shows how this is done. Isotherms rarely pass through a station and they must be inserted by using interpolation which is based on proportion.

ISOTHERMS IN DEGREES F



ISOTHERMS ARE DRAWN BY INTERPOLATION



How to Describe the Temperature State of the Air

When we talk about the climate of a region we nearly always use such adjectives as very hot, hot, warm or cool, etc. It is important therefore to give some temperature value to each of these adjectives. In the table A the temperature refers to daily, monthly or annual mean temperature. According to this table a month which has a mean temperature of 75° will be referred to as a hot month. A similar table (B) can be used for describing the mean annual range of temperature.

A

Temperature °F	State of the Air
Below 15° low	Very Cold
15° to 32°	Cold
32° to 50° mod.	Cool
50° to 70°	Warm
70° to 85° high	Hot
Over 85°	Very Hot

B

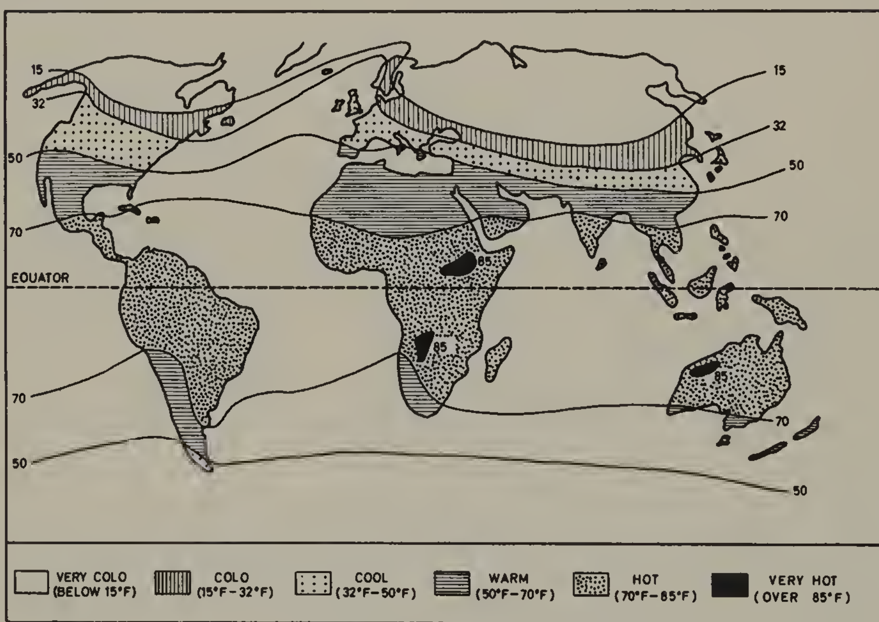
Annual Range of Temperature °F	Description
Below 5°	Negligible
5° to 15°	Small
15° to 35°	Moderate
35° to 55°	Large
Over 55°	Very Large

World Distribution of Temperature

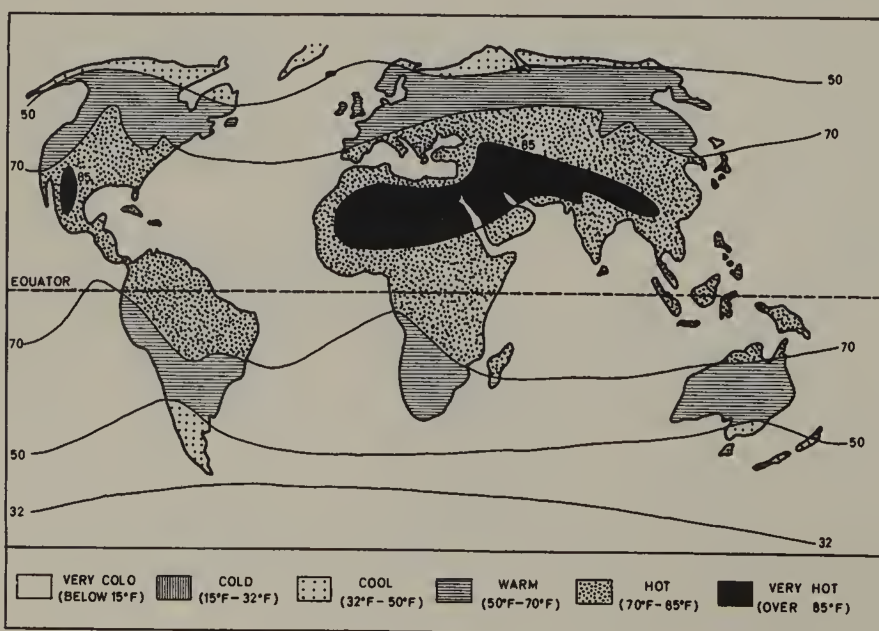
The maps show the mean temperatures for the months of January and July respectively. You should examine the isotherms of these two maps very carefully and then try to account for the following statements which can be made about these two maps.

1 There is a definite northward movement of all isotherms between January and July.
2 This movement of the isotherms is greater over the land than it is over the oceans.
3 The highest temperatures for both January and July are over the continents.
4 The lowest temperatures for January are over the northern continents (Asia and North America).
5 The isotherms bend poleward over the oceans but equatorward over the continents in January.
6 The isotherms bend equatorward over the oceans but poleward over the continents in July.
7 The seasonal changes are less marked over the southern continents than over the northern continents.

January Temperatures in °F



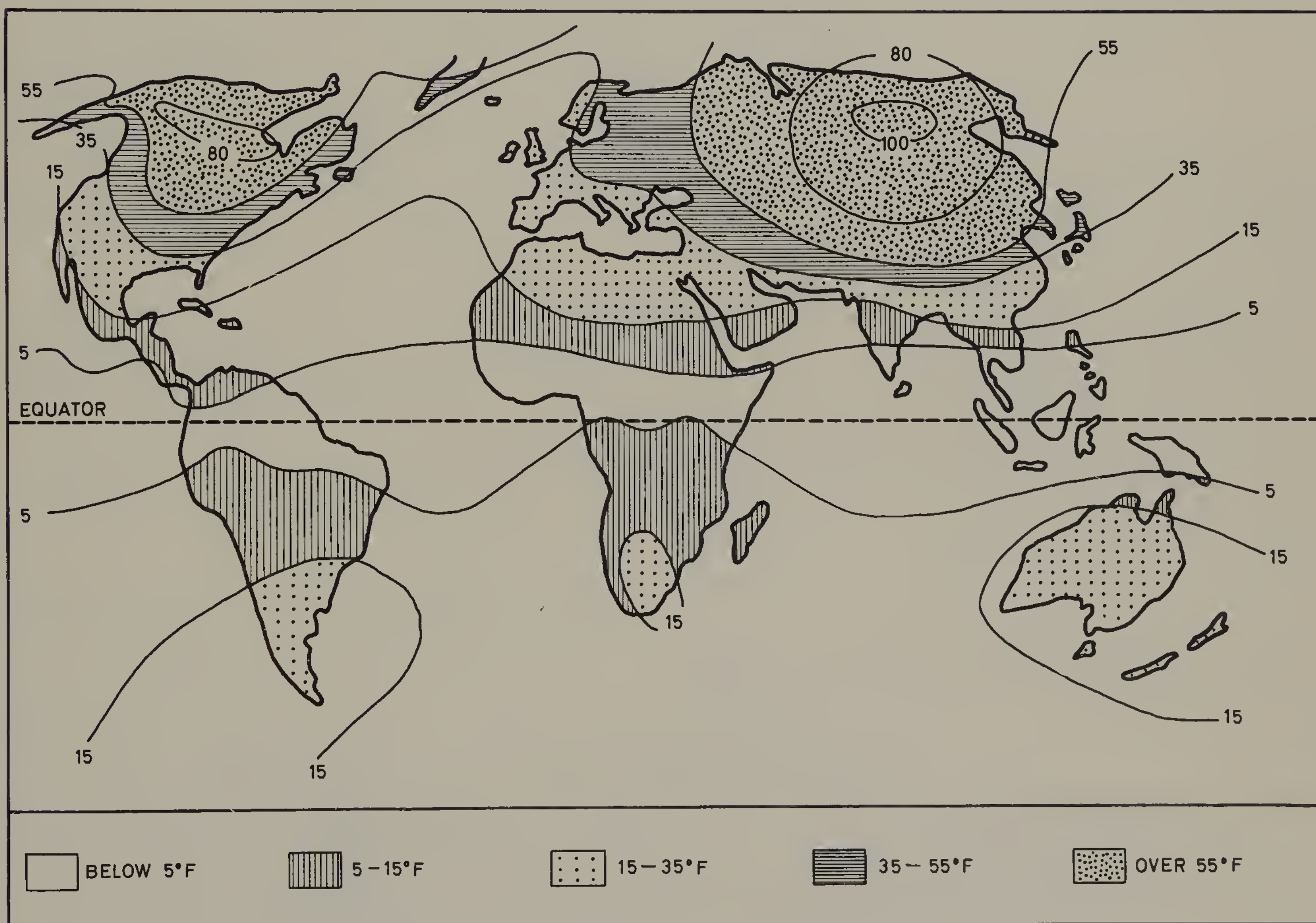
July Temperatures in °F



The mean monthly temperatures for January and July can be used to prepare a map to show the mean annual ranges of temperatures. This has been done in the map. The map indicates the importance of maritime and continental influences which will be discussed later. In the meantime study the map and, as with the previous two maps, try to account for these statements.

1 The range of temperature in general increases from the equator to the poles.
2 The greatest range of temperature occurs not at the poles but over Asia and North America in latitude 60°N (approx.).
3 Coastal regions have a smaller range of temperature than do continental interiors.
4 The range of temperature on the eastern sides of Asia and North America is greater than it is on the western sides in the *same latitude.*

Mean Annual Range of Temperature



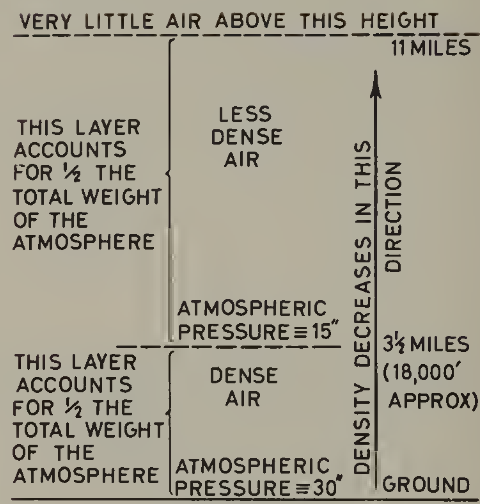
Pressure

We have already seen that air has weight and therefore it exerts a pressure, called atmospheric pressure, on the earth's surface. This pressure is not the same in all regions nor is it always the same in one region all the time. Atmospheric pressure depends on three factors:

1 *Altitude*
2 *Temperature*
3 *Earth Rotation*

Influence of Altitude on Pressure

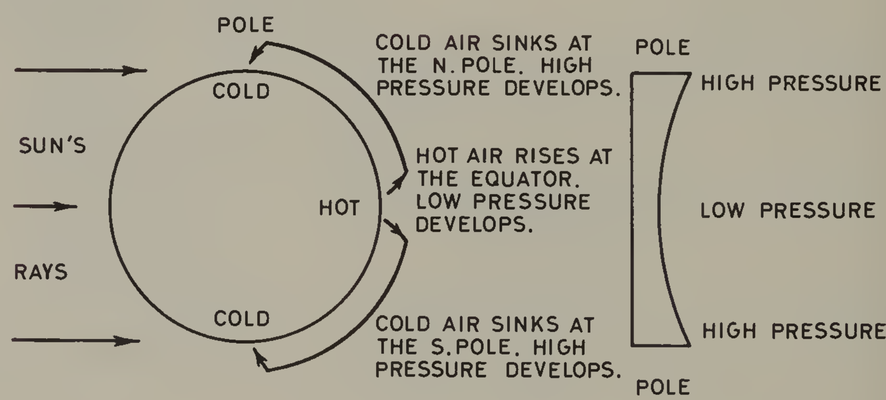
At sea level in the middle latitudes (45°N and 45°S) the average pressure is 1,013 mb (29.9″ barometric reading). In other latitudes at sea level the pressure is slightly different from this. In all latitudes places high above sea level have 'thinner' or less dense air than have places at sea level. As the density of the air decreases so does the pressure. Pressure therefore decreases as altitude increases. The rate at which pressure decreases is not constant because air at low altitudes is more dense than air at higher altitudes (see the top right diagram).



Influence of Temperature on Pressure

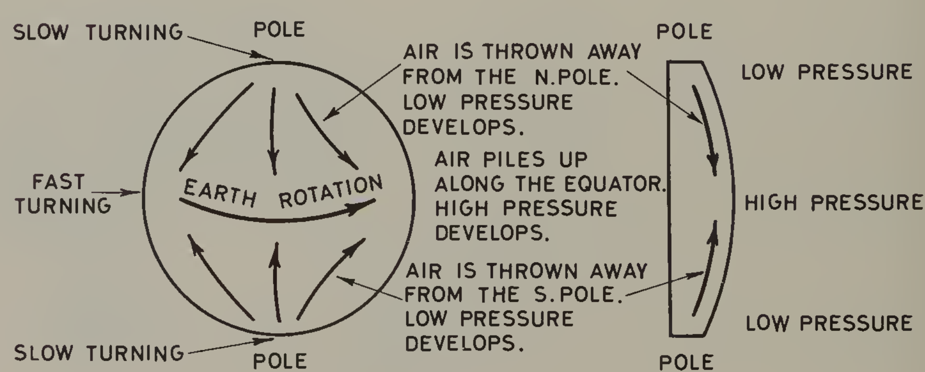
When the temperature rises air becomes less dense and its pressure decreases. When it falls air becomes more dense and its pressure increases.

Supposing that only temperature affected pressure, then the pressure pattern of the atmosphere would be something like that in the middle diagram. There would be a belt of low pressure around the earth at the equator, and two belts of high pressure, one over each pole. But because altitude and earth rotation (as well as temperature) affect pressure, the pressure pattern is not as simple as this.



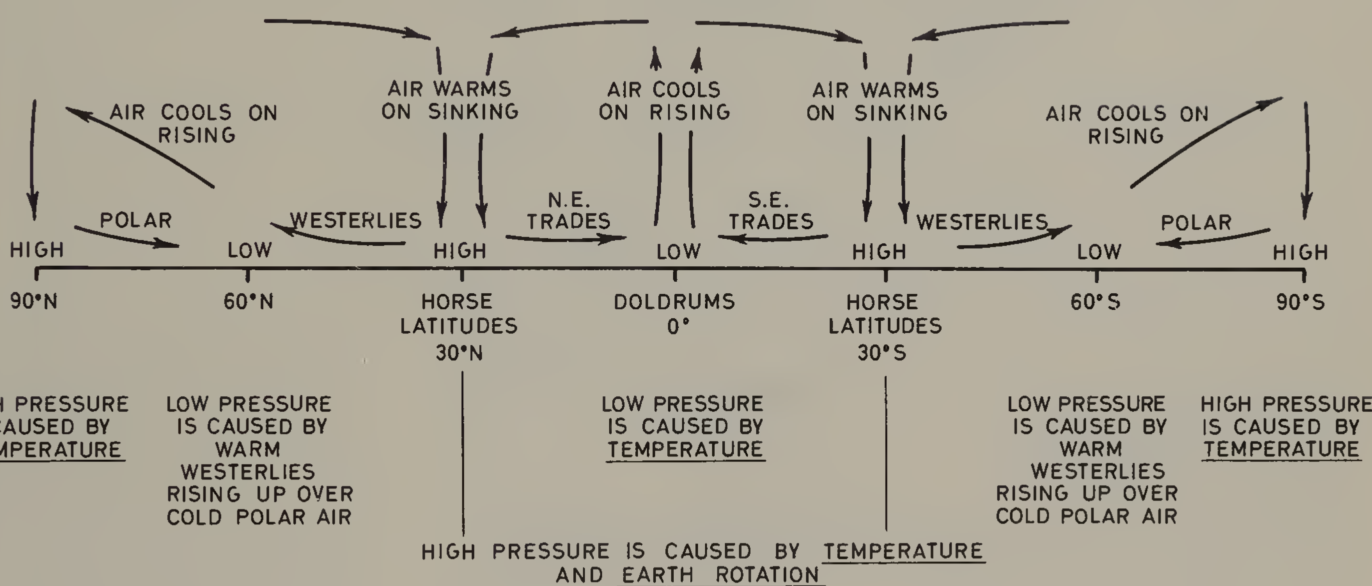
Influence of Rotation on Pressure

The poles are rotating more slowly than the equator, and, in theory, air should be thrown away from the poles towards the equator where it should pile up to form high pressure. At the poles there should be low pressure. This is shown in the bottom diagram.

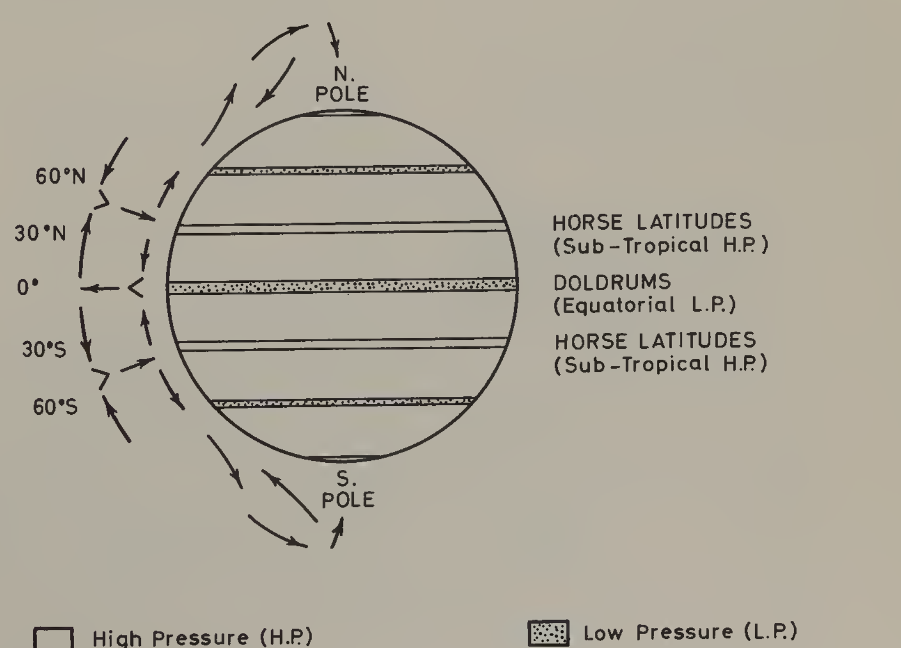


Combined Influence of Temperature and Rotation on Pressure

Let us first see what the combined influence would be on an earth with a uniform surface, i.e. all land or all water, and whose inclination was 90° (i.e. the sun would be overhead at noon at the equator on every day of the year). The pressure pattern on such an earth would be like that shown in the diagrams. Both diagrams are of course very simplified. Winds have been inserted because these are the product of the pressure systems. You will notice that there are winds both on the earth's surface and high above it. In our geography our main interest is in the surface winds and these have been named. You will see that winds blow from high pressure to low pressure. Later on you will be told how winds follow a curved path between the pressure belts. For the moment carefully study these two diagrams.

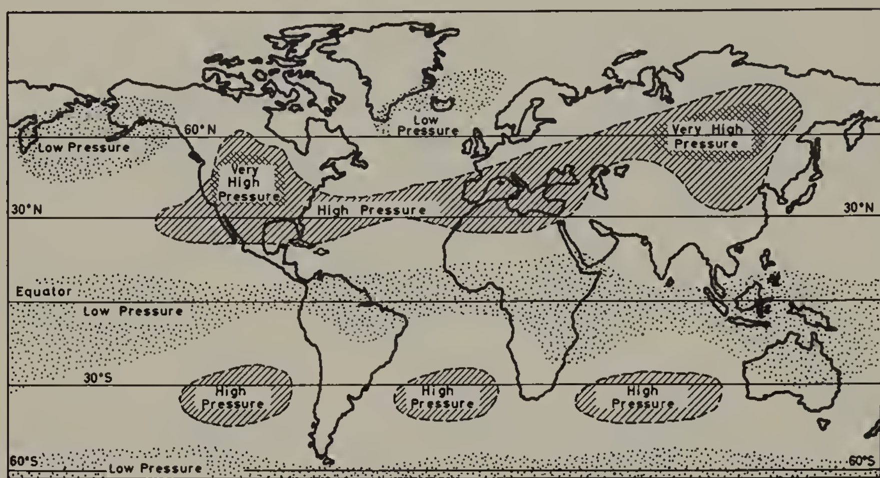


The hot air over the equator rises, cools and spreads out to the north and south. The cooling causes the air to descend. Also because of earth rotation the air banks up over latitudes 30°N and S. Thus the high pressures of the Horse Latitudes form. The Westerly Winds rising up over the cold polar air in latitudes 60°N and S produce low pressures. Cold descending air over the Poles gives rise to high pressures.



The Actual Pressure Systems on the Earth as it is

The earth's surface is not uniform, but is composed of land and water, and its axis is tilted at an angle of $66\frac{1}{2}°$. It has already been shown how land and water surfaces heat and cool at different rates, and also how temperatures in regions outside the tropics and especially over land surfaces vary considerably from season to season. All of this results in changes in the pressure systems as given in the diagram at the bottom of page 125. Study the pressure maps below which are for January and July and try to account for the differences.



Pressure for January

(i) The Equatorial Low Pressure Belt extends well into the Southern Hemisphere where it is the summer season.

(ii) Low pressure is particularly well developed over Australia.

(iii) The low temperatures over the hearts of the northern continents produce strong high pressure systems. These link up with the sub-tropical high pressure systems.

(iv) The sub-tropical high pressures of the Southern Hemisphere are formed only over the oceans.

(v) Low pressure systems are well developed over the North Atlantic and the North Pacific Oceans.

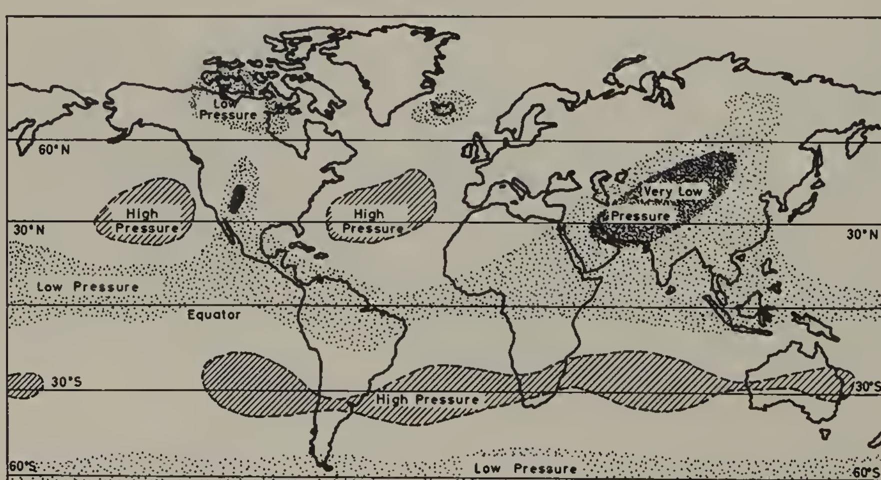
Pressure for July

(i) The Equatorial Low Pressure Belt extends well into the Northern Hemisphere where it is the summer season, and it links up with the low pressure belts over North West India and Pakistan and South West U.S.A. Pressure in these areas is very low.

(ii) The sub-tropical high pressure belt in the Northern Hemisphere is no longer continuous, and it now exists as separate cells of high pressure only over the oceans.

(iii) The sub-tropical high pressure cells of the Southern Hemisphere combine to form one belt of high pressure which extends across the three continents.

(iv) The low pressure cells over the North Atlantic and North Pacific Oceans are poorly developed and have moved north.



Points to remember about the Seasonal Changes in Pressure

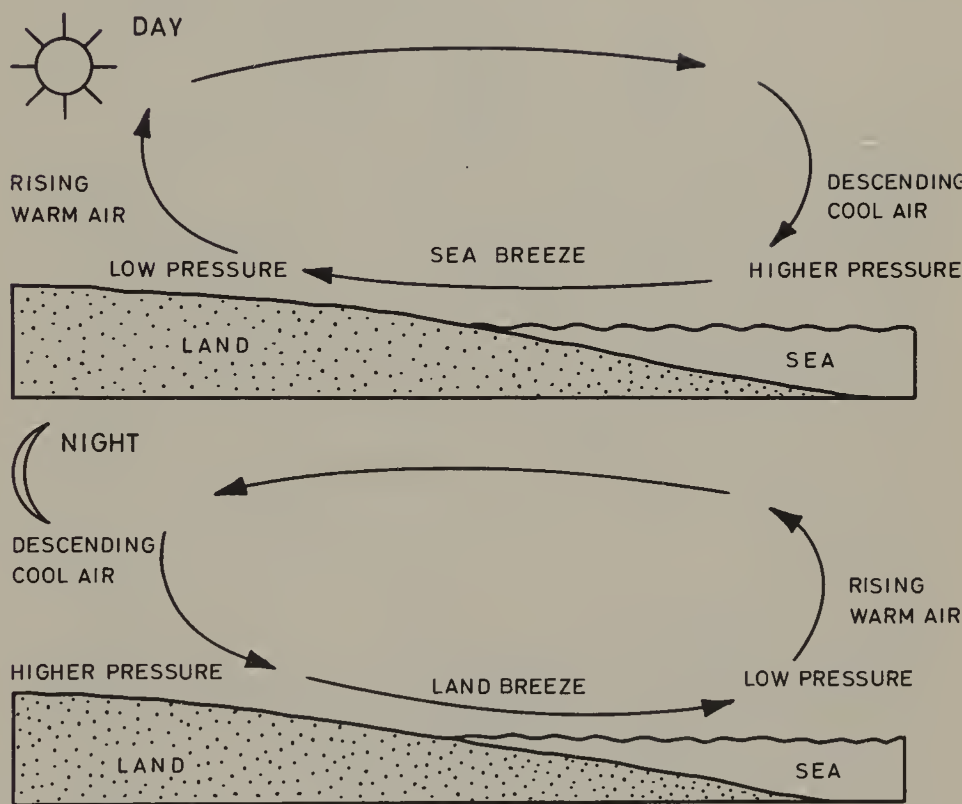
1 The revolution of the earth and the permanent tilt of its axis result in the overhead sun 'moving' between the Tropics as shown in the section dealing with the seasons. This causes the Doldrums to move north and south of the equator.
2 The Doldrums are the key to the pressure systems and hence these also move north and south of the positions they occupy when the sun is overhead along the equator (equinoxes).
3 Seasonal temperature changes over the continents in the Northern Hemisphere cause seasonal pressure changes over these continents.

Winds

In our work on pressure we have studied the relationship between temperature and pressure, and we have seen that:

1 A rise in temperature causes air to expand and its density to decrease.
2 A fall in temperature causes air to contract and its density to increase.

These statements mean that high temperatures give rise to low pressure at sea level, and low temperatures give rise to high pressure at sea level.



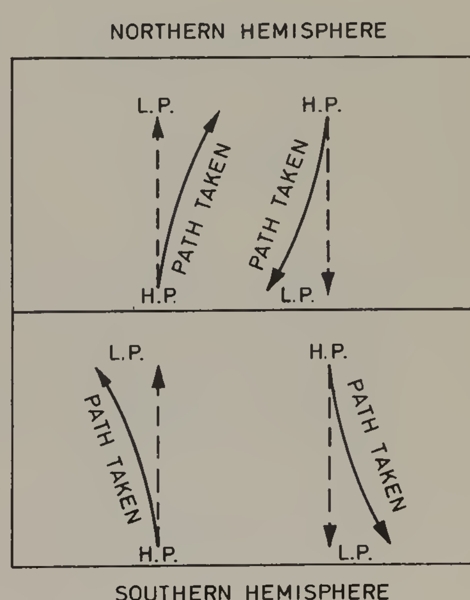
Land and Sea Breezes

When a region is hotter than a neighbouring region air moves into the hot region from the cooler region to take the place of the hot air which has expanded and risen. The air which moves in is a *wind*. The diagram explains how this comes about. During the day the land gets warmer than the sea and hence air pressure is lower over the land than the sea. Air blows from sea to land as a sea breeze. During the night the land cools more quickly than the sea and the reverse process sets in. Land and sea breezes illustrate this process particularly well.

Earth Rotation Influences Wind Direction

In an earlier part of this book (page 10) we saw that the rotation of the earth causes freely moving water and air masses to be deflected off their original courses. This is summarised by *Ferrel's Law* which states that freely moving bodies are deflected to their *right* in the Northern Hemisphere, and to their *left* in the Southern Hemisphere.

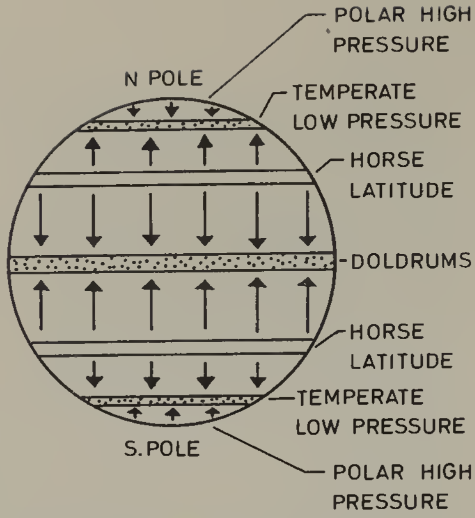
In the diagram dotted lines represent the paths which the winds would take if the earth was not rotating. Winds therefore do not follow straight paths, but curving ones as shown in this diagram.



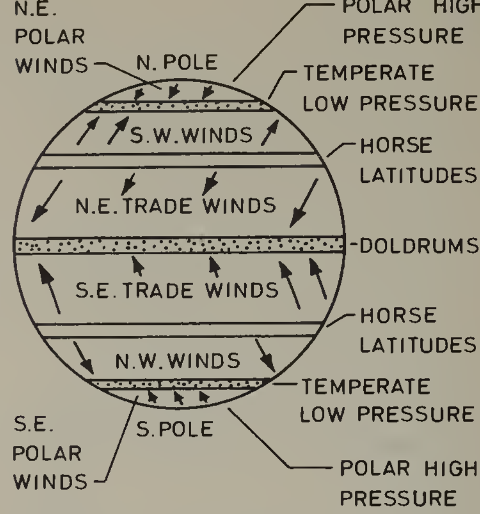
In both of these diagrams the earth is regarded as being uniform, i.e. all land or all water.

Prevailing Winds

A wind which blows more frequently than any other wind in a particular region is called a *prevailing wind*. The right diagram shows the prevailing winds of the world. You will notice from this diagram that winds are named by the direction from which they blow.



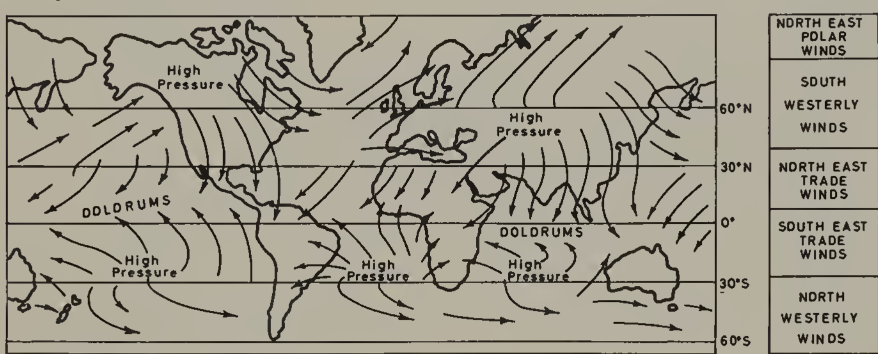
How the Winds would blow on a non-rotating earth



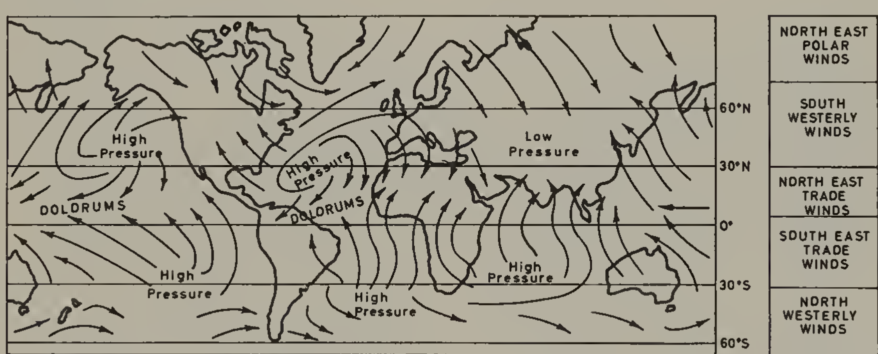
How the Winds blow on a rotating earth

WORLD PATTERN OF PREVAILING WINDS

January Wind Pattern



July Wind Pattern



These maps which show the wind patterns for January and July respectively should be carefully studied. Notice the following points:

(i) Over North America and Asia the winds are *out-blowing* during the winter when pressure is high, but are *in-blowing* during the summer when pressure is low.

(ii) The Westerly Winds in the Northern Hemisphere blow more persistently in winter than in summer. The Westerly Winds in the Southern Hemisphere blow persistently throughout the year.

(iii) The North East Trades over Asia are strengthened by the Asian High Pressure in winter, but completely disappear in summer because of the Asian Low Pressure.

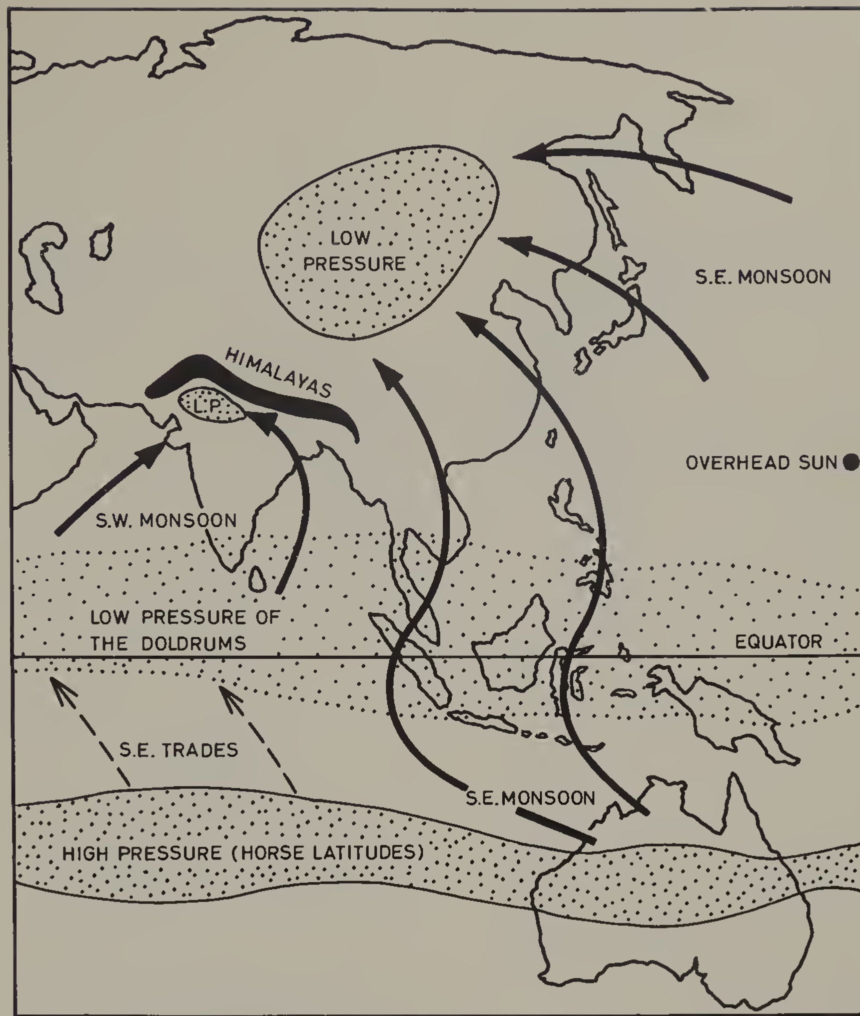
(iv) The North East Trade Winds in eastern U.S.A. disappear in the summer because of the American Low Pressure.

(v) All the wind belts in July shift slightly northward of their January positions.

We have seen that because the earth's surface is part land and part water, changes take place in the pressure belts from season to season (page 126). This is accompanied by changes in the pattern of winds. The basic wind pattern as shown in the top right diagram can be recognised in the wind patterns for both January and July. It only really breaks down over Asia and North America where winds change direction from season to season.

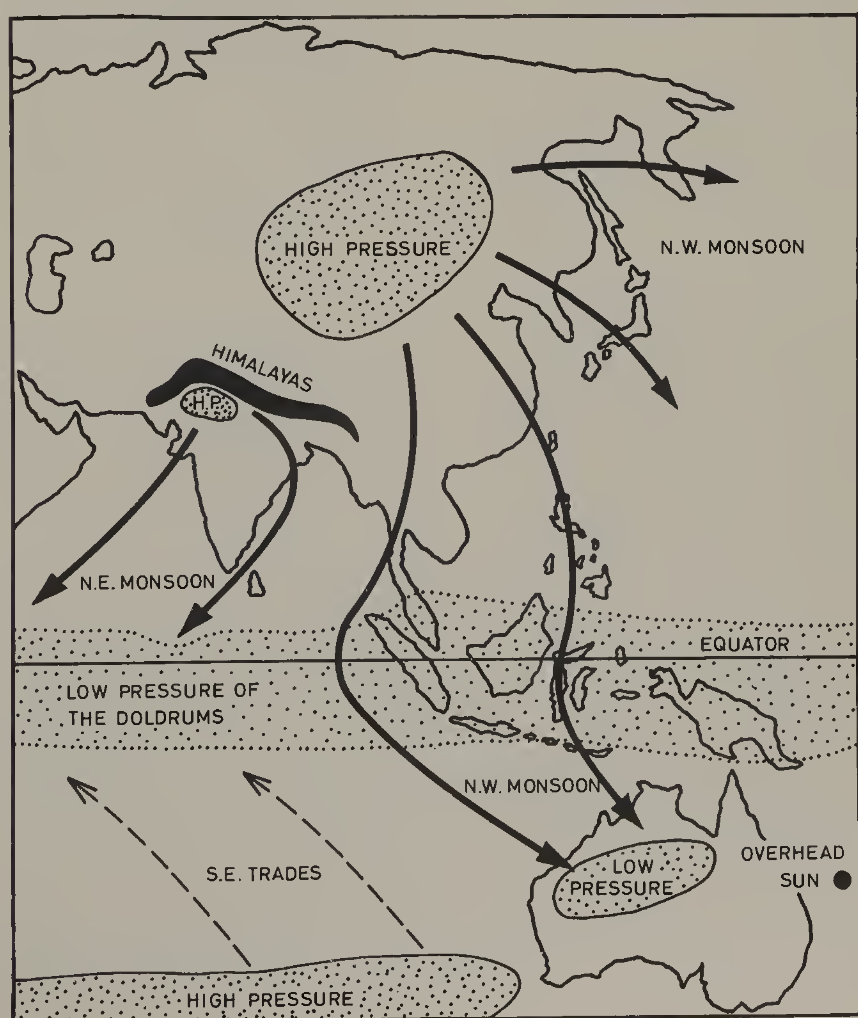
Monsoon Winds

Monsoon is derived from *mausim* (Arabic) which means *season*, and this word is applied to winds whose direction is reversed completely from one season to the next. Monsoon winds are best developed over Asia (Indian sub-continent, S.E. Asia, China and Japan).
In both diagrams the full black arrows represent monsoon winds. The arrows in broken lines represent non-monsoon winds.



July

1 The Himalayas separate the Asian Low Pressure from the Punjab Low Pressure.
2 Winds blow from the Australian High Pressure across the Equatorial Low Pressure to the more intense Asian Low Pressure.
3 Winds blow from the Horse Latitude High Pressure across the Equatorial Low Pressure to the more intense Punjab Low Pressure.



January

1 The Himalayas separate the Asian High Pressure from the Punjab High Pressure.
2 Winds blow from the Asian High Pressure across the Equatorial Low Pressure to the more intense Australian Low Pressure.
3 Winds blow from the Punjab High Pressure to the Equatorial Low Pressure.

Characteristics of the Prevailing Winds

Polar Winds

1 They blow from the Polar high pressures to the Temperate low pressures.
2 They are better developed in the Southern Hemisphere than in the Northern Hemisphere.
3 They are deflected to the right to become the N.E. Polar Winds in the Northern Hemisphere and to the left to become the S.E. Polar Winds in the Southern Hemisphere.
4 They are irregular in the Northern Hemisphere.

Westerlies

1 They blow from the Horse Latitudes to the Temperate low pressures.
2 They are deflected to the right to become the S. Westerlies in the Northern Hemisphere and to the left to become the N. Westerlies in the Southern Hemisphere.
3 They are not as constant in strength and direction as are the Trades.
4 They contain depressions (see section on cyclones).

Trades

1 The word trade comes from the Saxon word *tredan* which means to tread or follow a regular path.
2 They blow from the Horse Latitudes to the Doldrums.
3 They are deflected to the right to become the N.E. Trades in the Northern Hemisphere and to the left to become the S.E. Trades in the Southern Hemisphere.
4 They are very constant in strength and direction.
5 They sometimes contain intense depressions (see section on cyclones).

Cyclones (Depressions) and Anticyclones

Cyclone

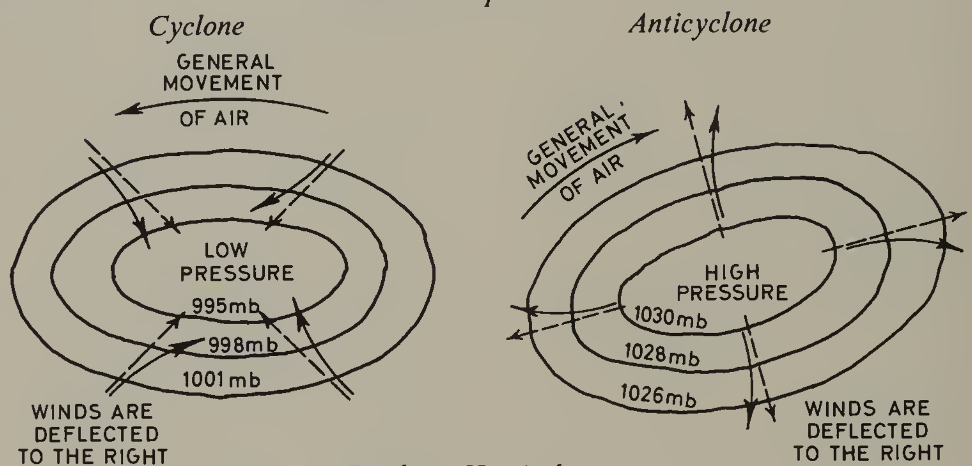
This is a mass of air whose isobars form an oval or circular shape, where pressure is low in the centre and increases towards the outside. A cyclone is also called a depression. Cyclones are well developed in the Westerlies and sometimes in the Trades.

Anticyclone

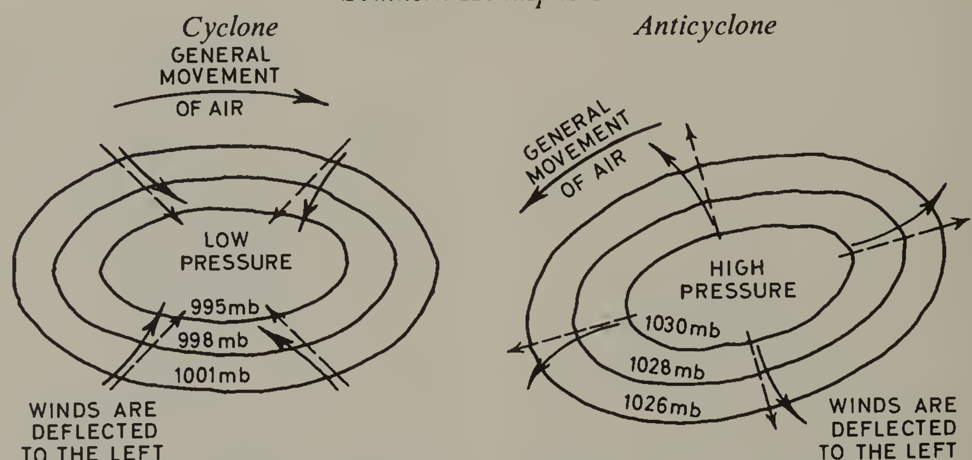
This is a mass of air whose isobaric pattern is similar to that of the cyclone, but pressure is high in the centre and it decreases towards the outside.

The wind circulation in cyclones and anticyclones is shown in the diagrams. You will see that air moves anti-clockwise in a cyclone and clockwise in an anticyclone in the Northern Hemisphere, and clockwise in a cyclone and anti-clockwise in an anticyclone in the Southern Hemisphere.

Northern Hemisphere



Southern Hemisphere



Types of Cyclones

There are two types:

1 Depressions (temperate cyclones).
2 Tropical cyclones (hurricanes and typhoons).

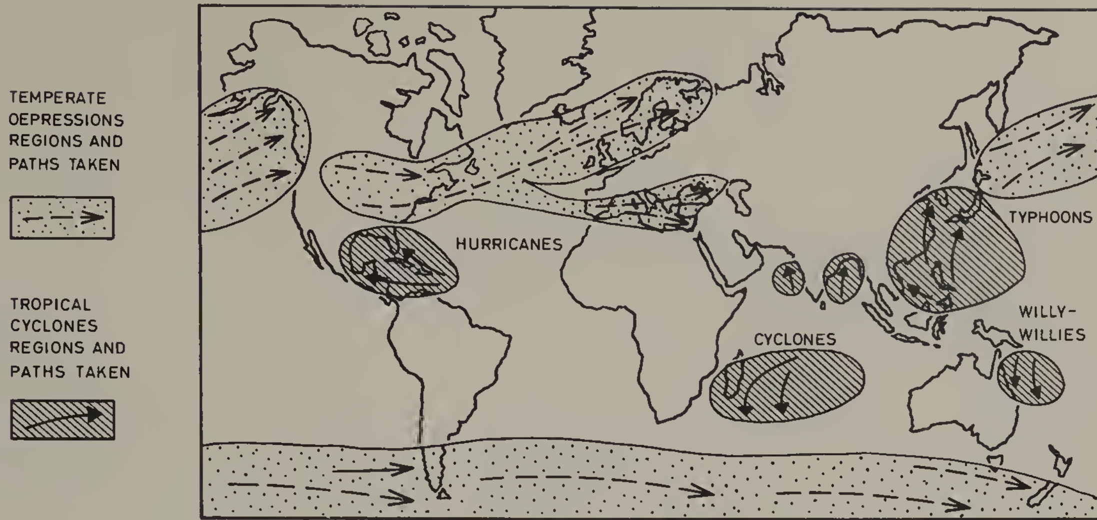
Depressions

These arise in the belt of Westerly Winds and are caused by the mixing of cold air from Polar regions with warm, humid air from Tropical regions. They consist of swirling masses of air (anti-clockwise in N. Hemisphere and clockwise in S. Hemisphere). They usually bring prolonged rain to coastal regions and often very windy weather.

Tropical Cyclones

These arise in the belt of Trade Winds where these winds begin to disappear in the Doldrums. They move in a general westerly direction and they have very low pressure. Because of this they give rise to winds of great force which are extremely destructive. Their circulation is the same as that of the depressions. In Asia they are called *typhoons*; in the West Indies they are called *hurricanes*.

Location and Movement of Cyclones



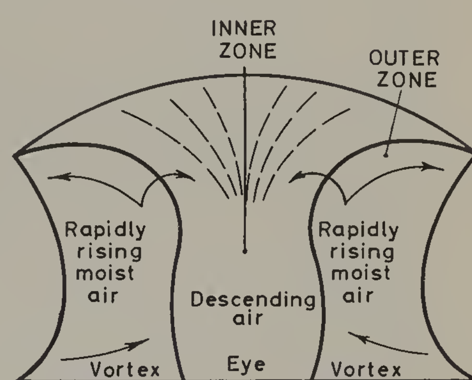
Tropical Cyclone

The middle diagram shows that a tropical cyclone is funnel-shaped. The air on the outside is rapidly rising and swirling in an anti-clockwise direction in the Northern Hemisphere. The air inside the funnel is relatively calm because it is descending.

The Nature of a Tropical Cyclone

1 Before the cyclone arrives the air becomes very still, and temperature and humidity are high.
2 As the front of the vortex arrives gusty winds develop and thick clouds appear.
3 When the vortex arrives, the winds become violent (upward surges) and often reach 150 miles per hour. Dense clouds and torrential rain reduce visibility to a few feet.
4 Calm conditions return when the eye of the cyclone arrives.
5 The arrival of the rear of the vortex brings in violent winds, dense clouds and heavy rain. The wind is now blowing from the opposite direction to that of the front of the vortex.

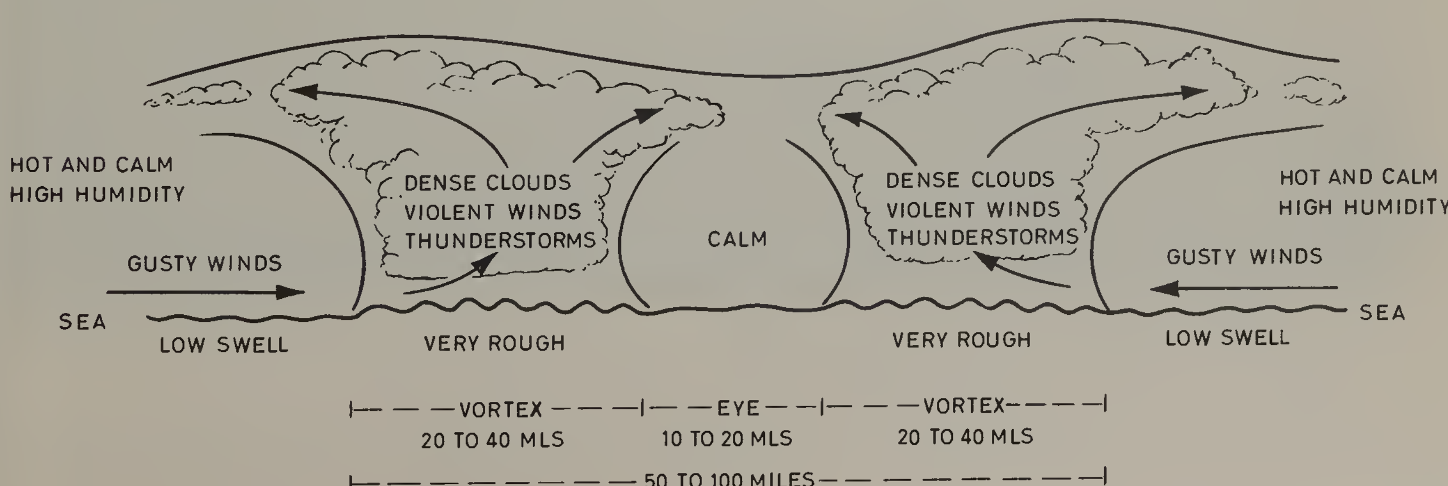
Section through a Tropical Cyclone



Where Tropical Cyclones form and what happens to them

They always form over the oceans in the tropics where the northerly and southerly trade winds meet. They follow an easterly course and soon lose their strength when they cross the coast and penetrate inland.

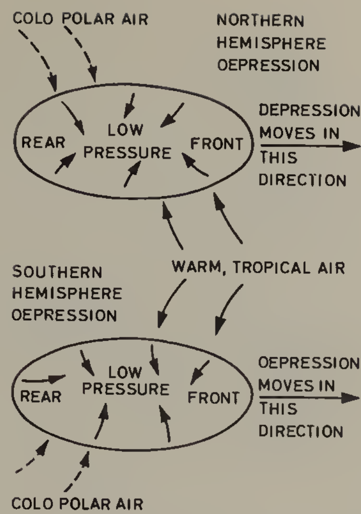
The Structure of a Tropical Cyclone



Tornado passing across southern U.S.A.

The uprising funnel of air is clearly visible. Although this is only a few hundred feet wide at the most it can cause tremendous damage by its 'vacuum' effect.

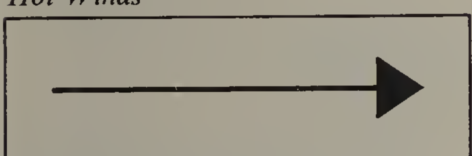
The different names given to tropical cyclones appear in the top diagram on page 131.
Tornadoes, which occur in the Mississippi Valley of U.S.A., have not been shown on this map. A tornado differs from a tropical cyclone in that it forms over land. It is more destructive than a cyclone because its winds often exceed 200 miles per hour.



Local Winds (affect only limited areas and blow for short periods of time)
Most local winds are developed by temperate depressions. The air circulation in these is such that air is drawn in from tropical regions in the front of the depression (this gives rise to hot winds), and from polar regions in the rear of the depression (this gives rise to cold winds) (top right diagram).

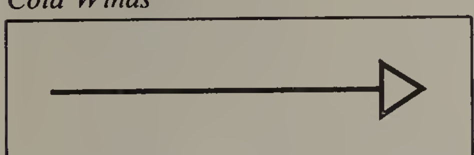
A **Depression Winds**

Hot Winds

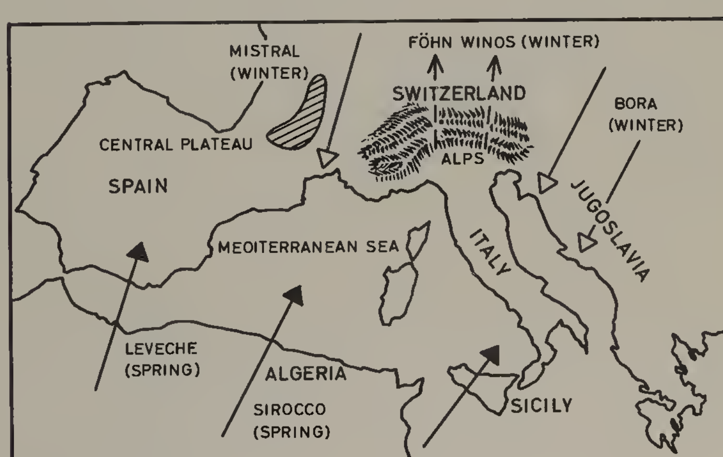


Usually these are both hot and dusty, but if they have crossed a sea surface they become very humid.

Cold Winds



Often very strong and gusty and bitterly cold.



B **Descending Winds**

These are warm winds which descend mountain slopes onto the lowlands. As the air rises up the windward side of the mountain it cools at the rate of 3.5°F per 1,000 ft. When condensation occurs, heat is given out, and the air cools at 2.5°F per 1,000 ft. After crossing the mountain the air descends and it warms as it does so. Warming takes place at the rate of 5.5°F per 1,000 ft. In the bottom diagram air on the windward side of the mountain at sea level is 45°F, whereas on the leeward side at the same level it is 59°F.

Descending winds occur in many regions but the best known are: *Chinook* (N. America—page 133); *Föhn* (Switzerland—page 133); *Berg* (South Africa—middle diagram) and the *Nor'wester* in South Island, New Zealand.

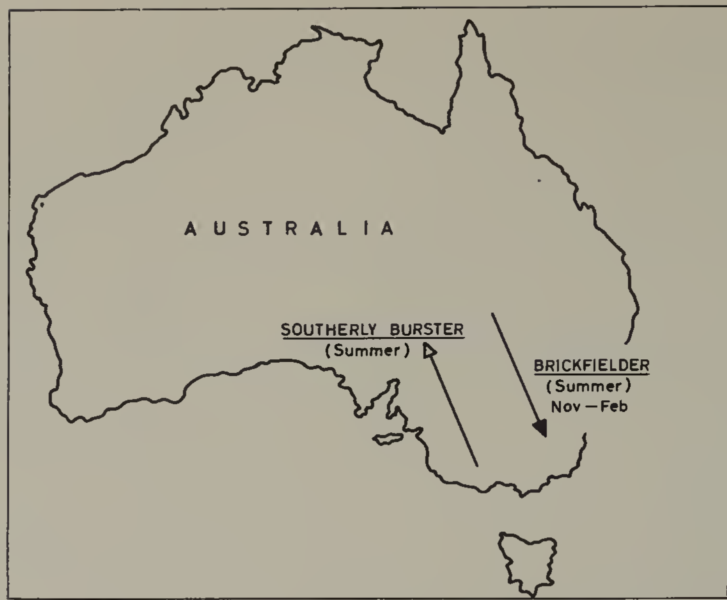
Summary of Local Winds

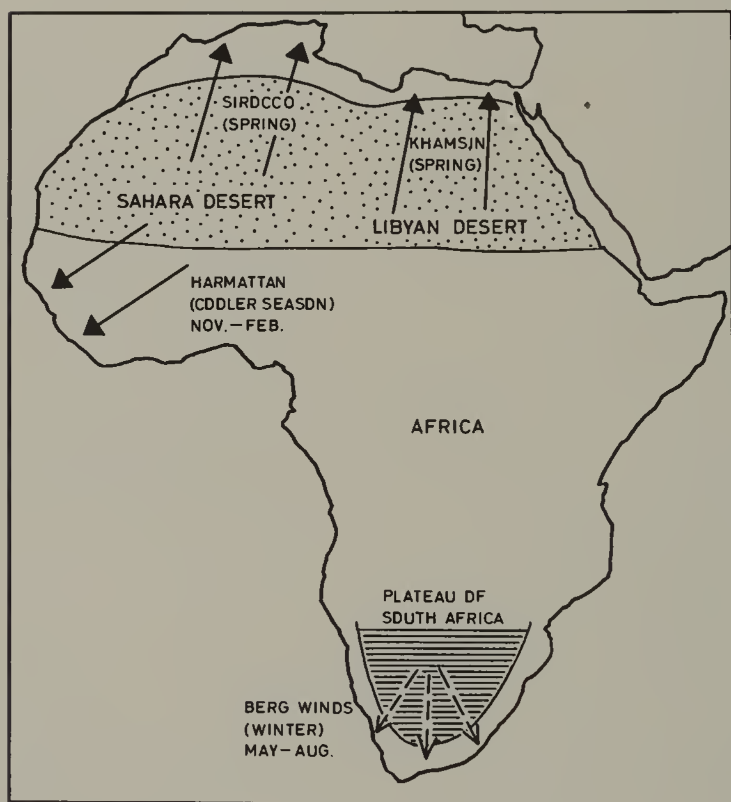
Depression Winds

Hot Winds	*Cold Winds*
Sirocco	Mistral
Leveche	Bora
Khamsin	Pampero
Harmattan	Southerly Burster
Santa Ana	Buran
Zonda	
Brickfielder	

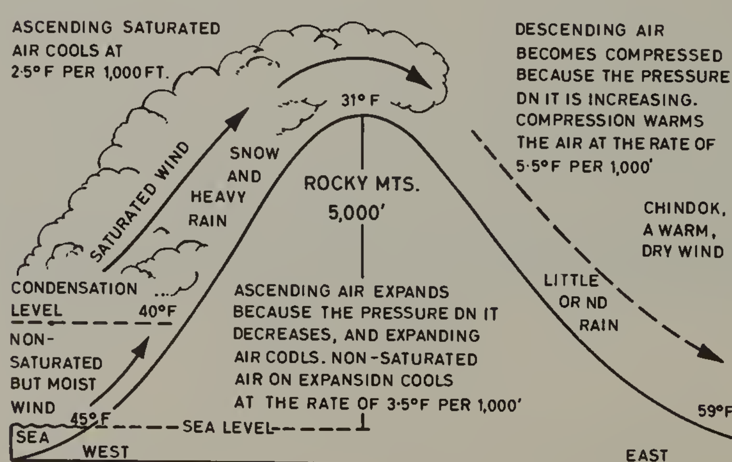
Descending Winds

Chinook
Föhn
Berg
Nor'wester
Samun (Persia)
Nevados (Ecuador)





Chinook Winds

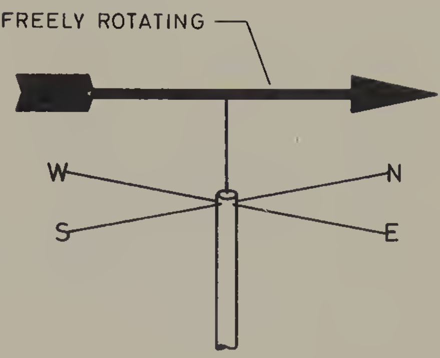


To Measure the Direction and Speed of the Wind

Wind direction is measured by a wind vane which consists of a rotating arm pivoted on a vertical shaft. The arrow of the wind vane always points in the direction from which the wind blows and the wind is named after this direction. Thus the diagram of a wind vane indicates that the wind is a north-east wind.

The speed of the wind is measured by an instrument called an anemometer. This instrument has three or four horizontal arms pivoted on a vertical shaft. Metal cups are fixed to the ends of the arms so that when there is a wind the arms rotate. This movement operates a meter which records the speed of the wind in miles per hour.

WEATHERCOCK



Recording of Winds

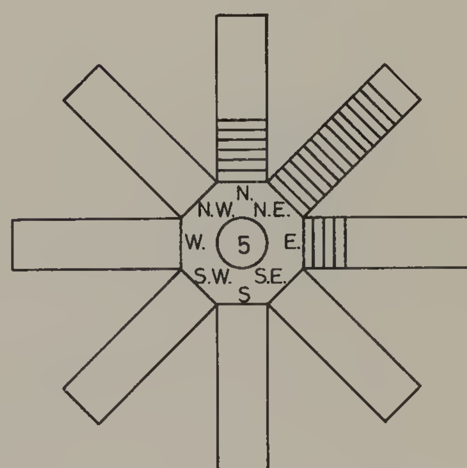
I *On a Map*

Winds are shown by arrows on a weather map. The shaft of an arrow shows wind direction, and the feathers on the shaft indicate wind force or speed. A half feather stands for a speed of 5 knots and a full feather a speed of 10 knots. A black pennant stands for a speed of 50 knots. Combinations of these can thus be used to show any speed. In practice the feathers do not have a definite value but indicate a speed between two limits. These values are given in brackets below the numbers 1, 5, and 10 and so on. Arrows are inserted at the positions of the weather stations on the map. The tip of the arrow away from the feathers points to the direction in which the wind is blowing.

KNOTS	WIND SYMBOL	KNOTS	WIND SYMBOL
1 (1-2)		15 (13-17)	
5 (3-7)		50 (48-52)	
10 (8-12)		55 (53-57)	
		60 (58-62)	

II *On a Wind Rose*

The main purpose of a wind rose is to record wind direction for a specific place. A simple wind rose is shown in the bottom right diagram. It consists of an octagon, each side of which represents a cardinal point. Rectangles are drawn on each side and each day when there is a wind a line is ruled across the rectangle representing the direction from which the wind is blowing. This is done for one month. The number of days when there is no wind is recorded in the circle in the centre of the octagon. The diagram shows the type of wind pattern Singapore often gets during December.



Rainfall

Under certain conditions water vapour, which is a gas, takes the form of tiny droplets of water. These appear as a cloud, mist, fog, hail, dew or rain. All of these forms are referred to as precipitation.

Conditions necessary for Precipitation to Occur

1 The air must be saturated.

2 The air must contain small particles of matter such as dust around which the droplets form.

3 The air must be cooled below its dew-point.

How Air is Cooled

Air is cooled in two main ways:

1 *By being made to rise*—(most of the world's rain results from this type of cooling)

- (i) A wind blowing over a mountainous region (middle diagram)
- (ii) Hot air rising by convection currents (top diagram)
- (iii) Warm air rising over cold air.

2 *By passing over a cold surface*—(most of the world's mist and fog results from this type of cooling)

- (i) A warm wind blowing over a cold current
- (ii) A warm wind blowing over a cold land surface.

Oceans and ocean currents influence rainfall

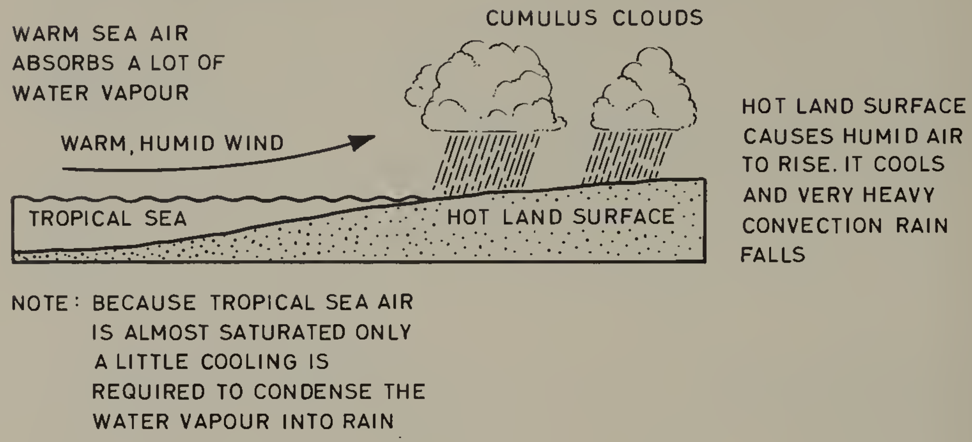
The importance of oceans as a source of rainfall is well known. In tropical latitudes the air over the oceans contains much more water vapour than does the cooler air over the oceans in temperate latitudes. But remember not all tropical regions have heavy or even fairly heavy rainfall.

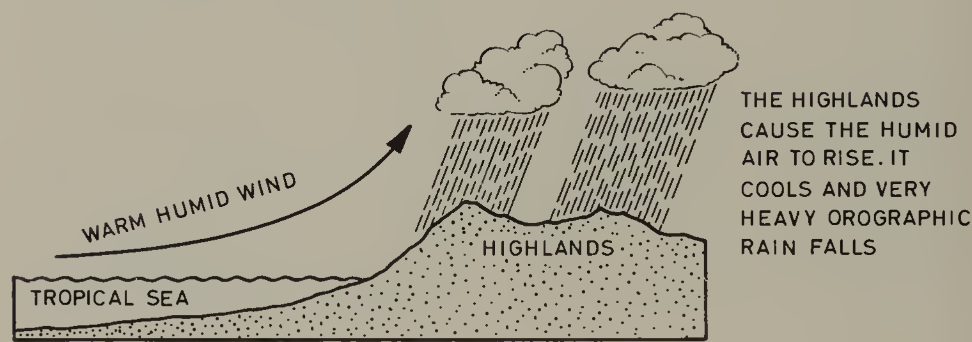
- (i) Winds blowing over a warm current on to a cooler land surface usually bring heavy rain.
- (ii) Winds blowing over a cool current on to a warmer land surface usually bring little or no rain.
- (iii) Winds blowing over a warm current and then over a cold current usually produce fog.

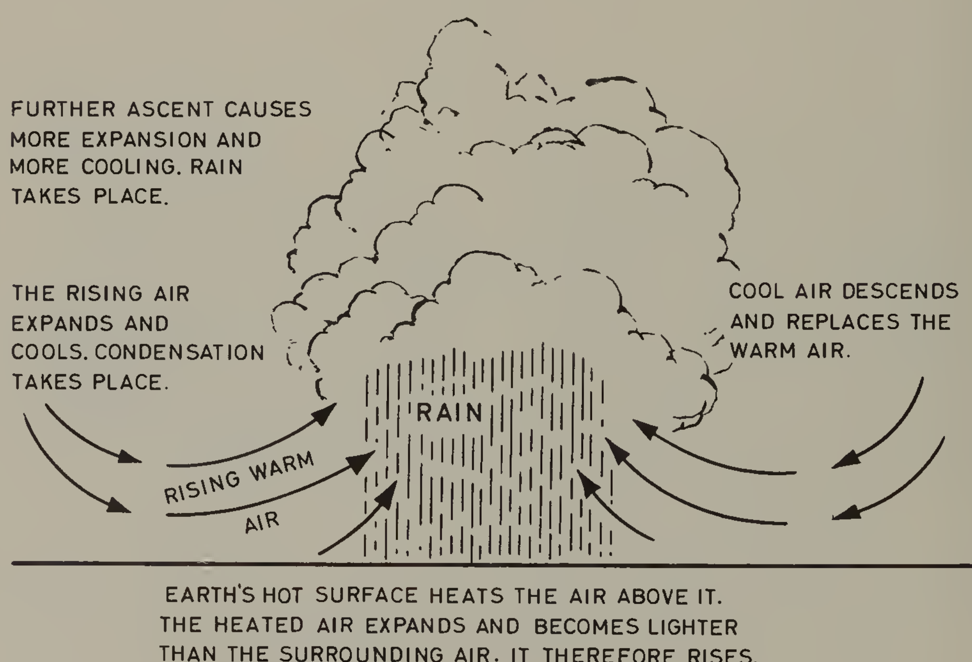
Types of Rainfall

I *Convection Rain*

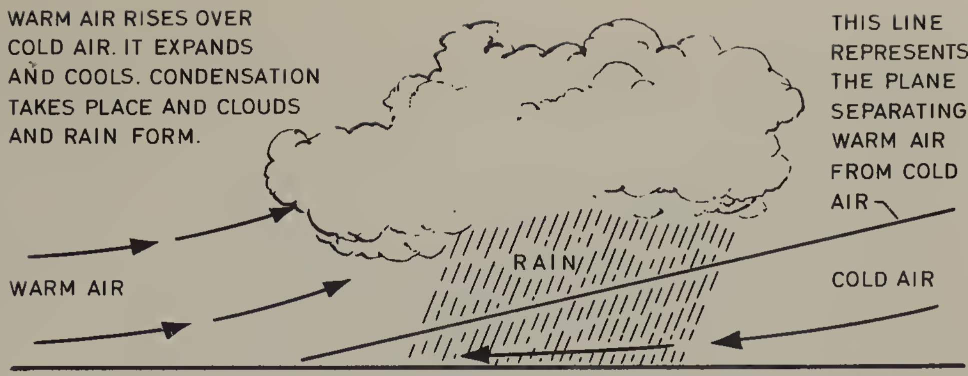
Convection rain is often accompanied by lightning and thunder. In tropical latitudes this type of rain is usually torrential. It is the most common type of rain to fall in Equatorial Regions and in regions having a Tropical Monsoon Climate.



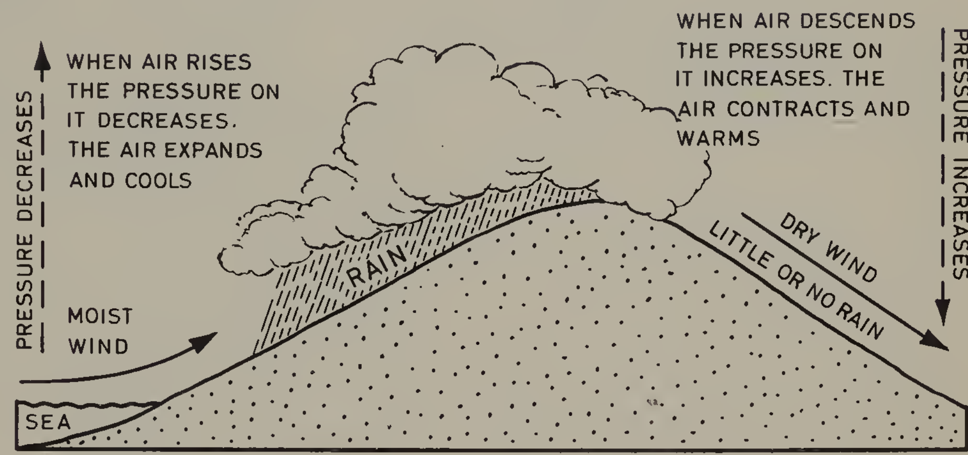




II *Depression or Cyclonic Rain*
Depression rain occurs when large masses of air of different temperatures meet. The warm air is forced up and over the cooler air. In tropical cyclones the rainfall is often very heavy but lasts for only a few hours. In temperate depressions it is much lighter but lasts for many hours or even days. Cyclonic rain is common throughout the Doldrums where the trade winds meet.



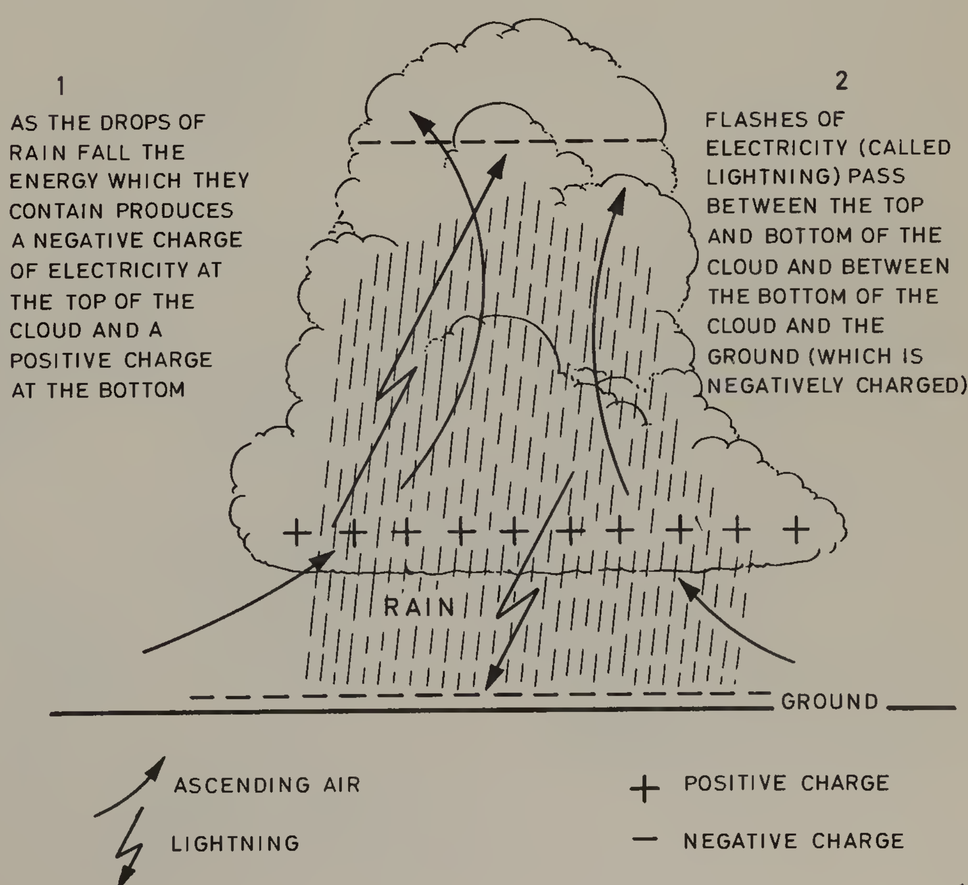
III *Orographic or Relief Rain*
Whereas convection rain only occurs in regions whose surfaces are greatly heated by the sun, and cyclonic rain only occurs where masses of air of different temperatures meet, orographic rain occurs in all latitudes. It is most common where on-shore winds rise up and over hilly or mountainous regions lying parallel to the coasts.



Thunderstorms can occur whenever land surfaces become greatly heated. In humid tropical regions like Indonesia, Malaya, Central and West Africa, the Amazon Basin and Central America, thunderstorms are very common. They usually occur in the afternoon and are especially frequent in the season of heavy convectional rains.

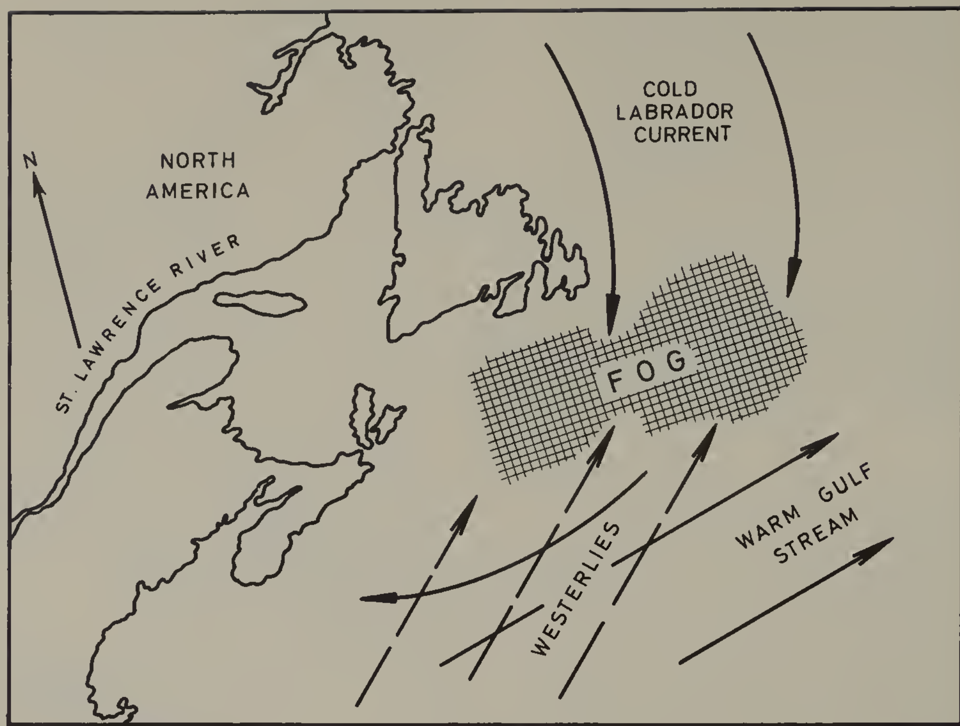
The thunder of these storms is caused by the rapid expansion and contraction of the air. The electrical discharges (lightning) produce intense heat which causes the air to expand. Cooling soon takes place and the air contracts.

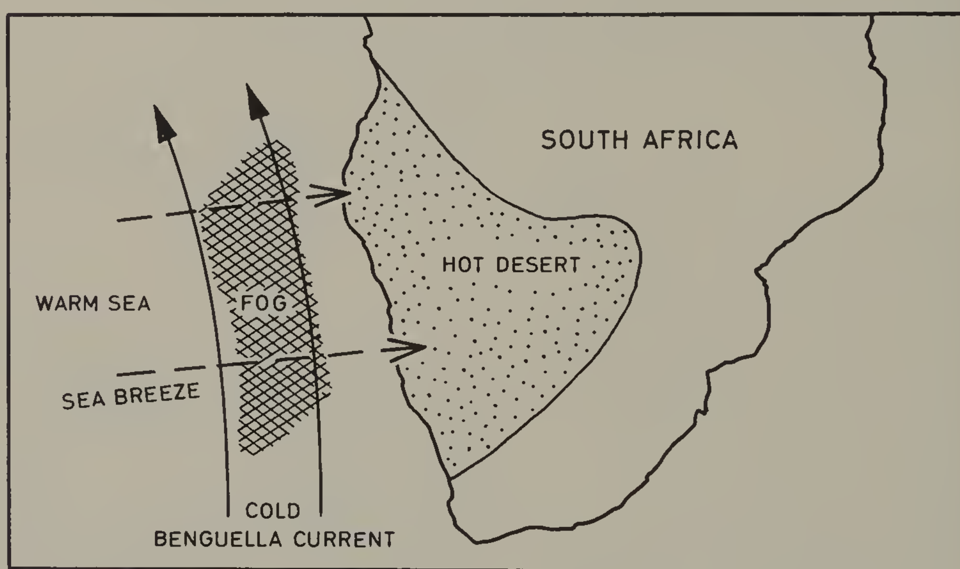
A Thunderstorm



Fogs

Extensive fogs develop where warm and cold currents meet and where warm moist winds blow over cold surfaces. Fogs are very frequent off the mouth of the St. Lawrence (top map) and round the shores of Japan where the warm Kuro Siwo and the cold Oya Siwo (Okhotsk) meet. They often develop off the west coasts of hot deserts where warm sea breezes pass over the cold off-shore current. The sea breezes are only local winds but they give rise to belts of mist or fog just off the coasts. Examples of this type occur off the coasts of California, Peru, N.W. Africa and S. Africa (lower map).

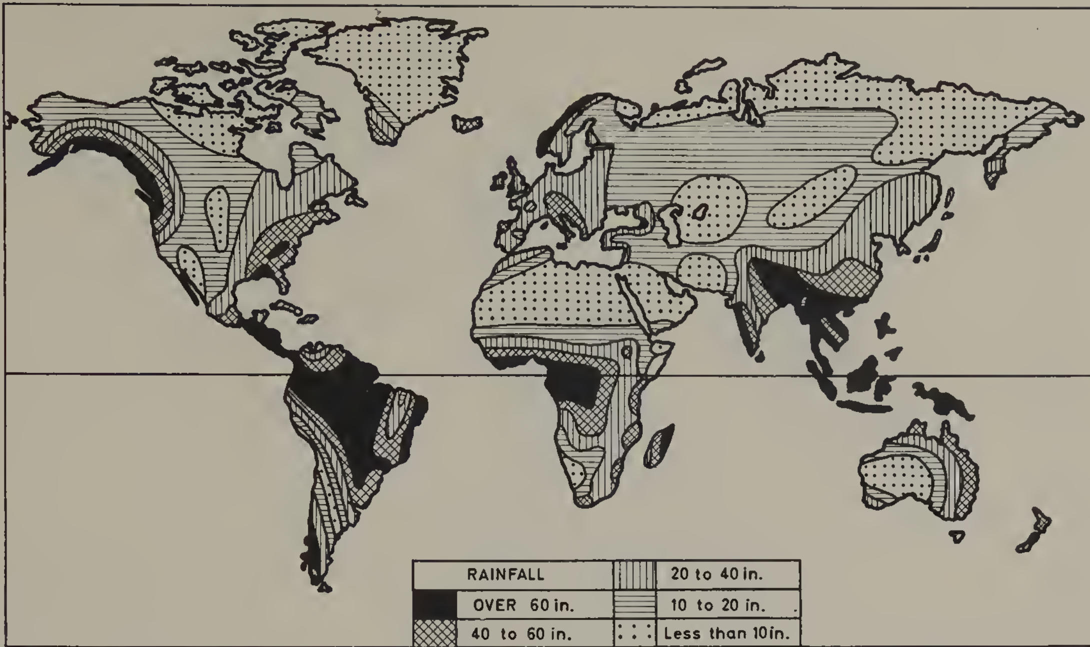




The World Pattern of Rainfall

We have already studied how the revolution of the earth and the tilt of its 'axis' result in a movement of some pressure belts and a change in others, and how this in turn causes the belts of prevailing winds to move northwards and southwards, and other wind belts to change direction during the year. Let us now see how this affects the rainfall pattern of the world. First, we will examine the map at the top of page 139 which shows the mean annual rainfall.

Mean Annual Rainfall for the World



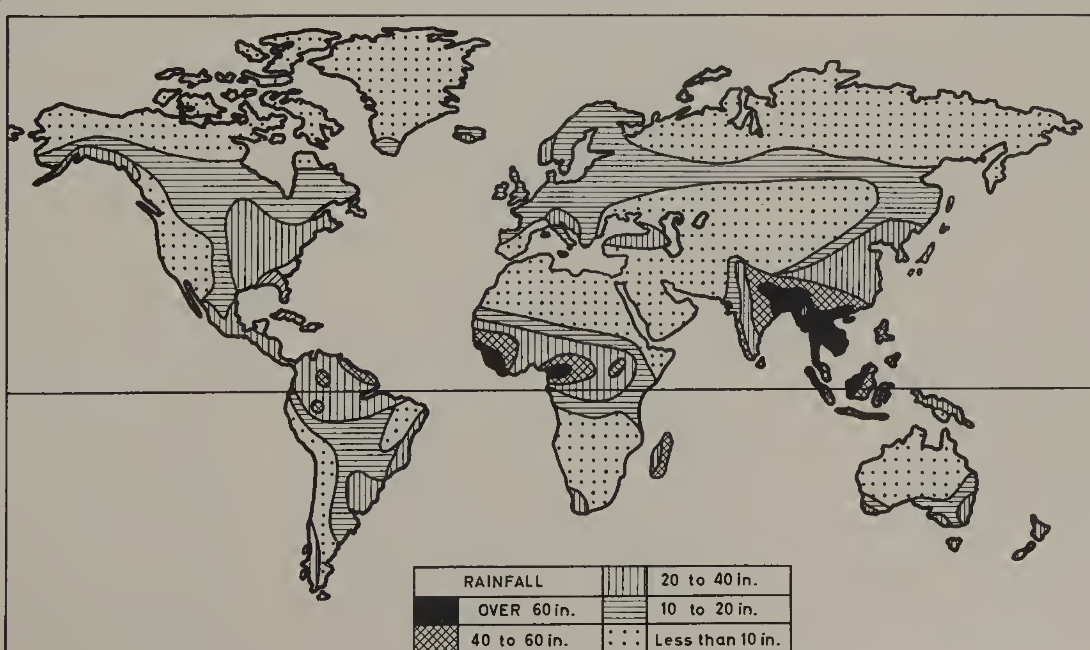
In this map the world has been divided into five types of rainfall region on a basis of the amount of rain received annually. Notice the following points.

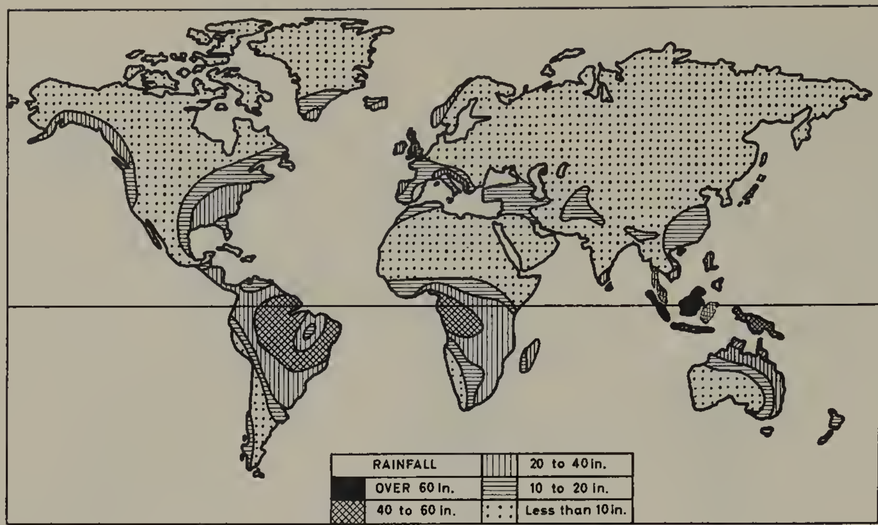
1 The wettest regions (over 60 ins.) occur in:
   (i) *Equatorial Latitudes* (Amazon and Congo Basins, Indonesian Islands, Malaya and New Guinea)
   (ii) *Tropical Monsoon Regions* (S. China, Peninsular S.E. Asia, E. Pakistan, N.E. India and W. India, Ceylon and the Philippines)
   (iii) *Regions receiving on-shore Westerly Winds* (British Columbia, N.W. Europe, S. Chile, Tasmania, South Island of New Zealand).

2 The driest regions (less than 10 ins.) occur in:
   (i) *Hearts of N. America and Asia*
   (ii) *Regions lying permanently under off-shore Trade Winds* (Sahara and Arabian Deserts, Australian Desert, Kalahari and Atacama Deserts and the deserts of S.W. States of U.S.A.)
   (iii) *Arctic Lowlands* (N. America, Greenland and Asia).

Now this map only tells us how much rain a region receives each year. It doesn't tell us at what time of the year the rain comes. When we study agriculture, i.e. the types of crops grown on the earth's surface, it is necessary to know both the amount of rain falling in a region in one year and the time of year when it comes. The map below and on page 140 show the distribution of rain for the world during the summer and winter seasons.

Distribution of Rain — *May 1st to October 31st*





May 1st to October 31st
(See map on page 139)

1 The sun is overhead in the Northern Hemisphere and most of the rain falls in this hemisphere.
2 The belt of equatorial convection rains is chiefly located north of the equator.
3 Southern and eastern Asia, eastern N. America and Central America receive heavy rain from on-shore winds.
4 Extensive areas in S.W. Asia, N. Africa, N. and Central Australia, S. Peru, N. Chile, S.W. States of N. America, and S.W. Africa receive little or no rain because they lie under off-shore trade winds.
5 The Arctic lowlands receive little rain because of low temperatures which prevent the air from absorbing much water vapour.

November 1st to April 30th
(see map above)

1 The sun is overhead in the Southern Hemisphere and most of the rain falls in this hemisphere.
2 The belt of equatorial convection rain is chiefly located south of the equator.
3 N. and E. Australia, S.E. Africa and S.E. Brazil and E. Argentina receive rain from on-shore trade winds. (In N. Australia rain is brought by monsoon winds which are modified N.E. Trade Winds.)
4 Extensive areas of S.W. Asia, N. Africa, Central and E. Australia, eastern U.S.A., S. Peru, N. Chile and S.W. Africa receive little or no rain because they lie under off-shore trade winds.
5 The Arctic Lowlands as before have little or no rain.

The Migration of the Overhead Sun and the Rainfall Pattern

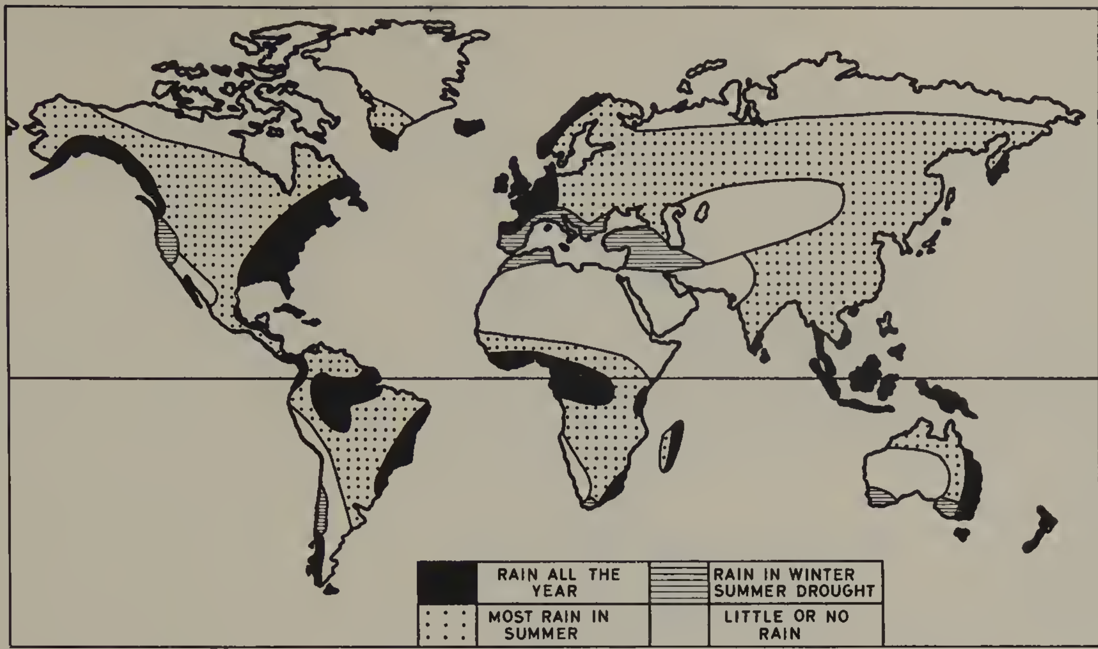
A *Some regions are NOT influenced*

1 Regions permanently in a belt of prevailing winds:
   (i) N.W. Europe, W. Canada, S. Chile, Tasmania, South Island (N.Z.).
   They lie in the belt of on-shore Westerlies (rain all the year).
   (ii) S. California, S. Chile, Sahara, S.W. Asia, Australian and Kalahari Deserts.
   They lie in the belt of off-shore Trades (little or no rain throughout the year).
2 Regions permanently in the doldrums belt, e.g. Islands of S.E. Asia, Congo and Amazon Basins. They receive convection rain throughout the year.

B *Some regions ARE influenced*

1 Regions lying between two belts of prevailing winds:
   Central California, Central Chile, Mediterranean Lowlands, S.W. Australia.
   They lie between the Westerly and Trade Wind belts. The Westerlies bring rain in the cool season; in the warm season the Trades blow and there is no rain.
2 The interiors of Asia and N. America. In these regions atmospheric pressure is low in summer. In-blowing winds give rain and intense heat causes convection rain. In winter atmospheric pressure is high and winds are out-blowing. There is little or no rain.
3 Regions bordering the permanently wet equatorial regions lie under the doldrums once a year and this results in heavy convection rain. They also lie under the Trades once a year. Where these are off-shore there is little or no rain. These regions lie in S. America, Africa and Australia and they have a *savana climate* (see page 145).
4 Monsoon Regions:
   Japan, China, Peninsular S.E. Asia, India, E. Pakistan, Ceylon and N. Australia.
   For one season they lie under on-shore winds which bring rain. For the other season they lie under off-shore winds which bring little or no rain.

Seasonal Distribution of Rain



In this map the world has been divided into four types of rainfall region. The four types are:

(i) Regions receiving rain throughout the year
(ii) Regions receiving rain chiefly in the hot season (summer)
(iii) Regions receiving rain chiefly in the cool season (winter)
(iv) Regions receiving little or no rain.

The following statements can be made about this map:

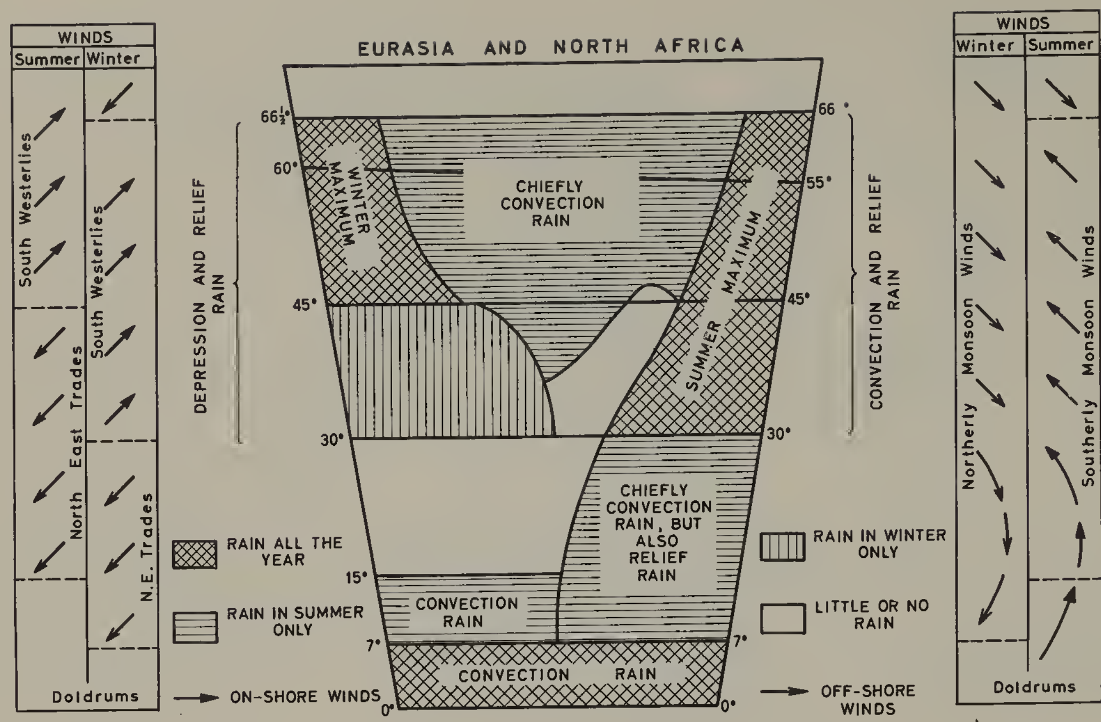
1 *Regions having rain all the year are located in:*
(i) Equatorial and some tropical latitudes
(ii) Coastal regions where winds are on-shore for most of the year.

2 *Regions having rain in the summer are located in:*
(i) Most of Asia excluding Malaysia and Indonesia and New Guinea
(ii) E. Europe
(iii) N. Australia
(iv) Regions bordering the equatorial latitude of Africa and S. America
(v) Central N. America.

3 *Regions having rain in the winter are located in:*
(i) Central California and Central Chile
(ii) Mediterranean Lowlands
(iii) S.W. Africa and S.W. Australia.

4 *Regions having little or no rain are located in:*
(i) S. California and S.W. States of N. America
(ii) The Atacama and Kalahari Deserts
(iii) The Sahara, Arabian and Asian Deserts
(iv) The Australian Desert
(v) The Polar Deserts.

Seasonal Rainfall and Type of Rain



Above is a diagrammatic representation of Eurasia and N. Africa and shows the seasonal distribution of winds and rain together with the type of rain. The winds on the left-hand side operate over the western part of the region and those on the right-hand side operate over the eastern part of the region. Examine this figure and pay particular attention to the following:

(i) The north–south shift of some wind belts, and the change in wind direction of other belts from season to season.

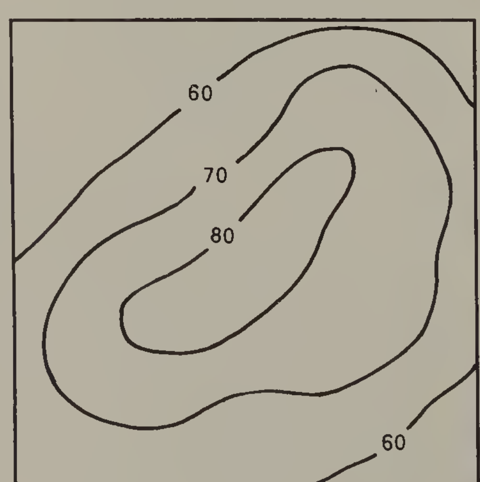
(ii) The location of on-shore winds (which usually bring rain) and of off-shore winds (which usually bring no rain).

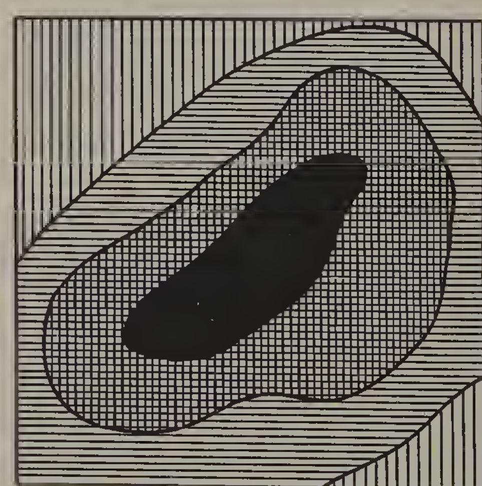
(iii) The distribution of rain in relation to the lines of latitude which are given.

Recording of Rainfall on a Map

Lines are drawn on the map through all places having the same rainfall. Such lines are called *isohyets*. They are drawn at a uniform interval (in the first diagram on the right this is 10). A scale of colours or line shading (see second diagram on right) is then worked out and applied to the map. It is usual to start with light colours or open lines for low rainfall and to use darker colours or closer lines for heavy rainfall.

Rainfall maps may show seasonal or annual values.





Chapter 8 Types of Climate

All of us know that some regions are hot and others are cold; some are wet and others are dry; some have rain all the year and others have rain in a part of the year only.

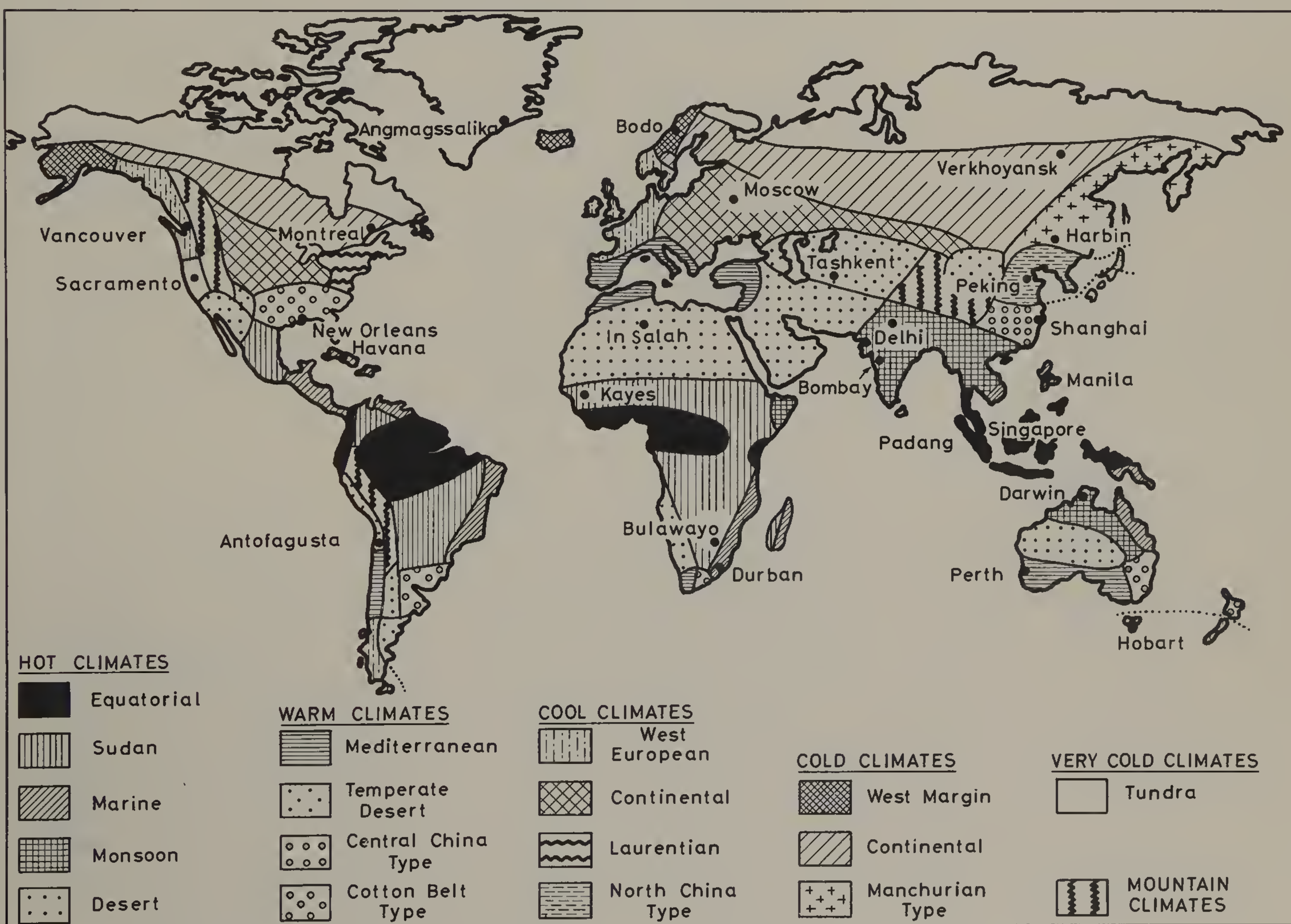
The world can be divided into climatic regions, each of which has a distinct temperature and rainfall pattern. This can be done by dividing the world into five temperature zones:

Hot Zone; Warm Zone; Cool Zone; Cold Zone; Very Cold Zone.

Now each of these zones is very large, and, with the exception of the very cold zone,* the rainfall distribution is not even, i.e. one part of a zone may be wet whilst another part of the same zone may be dry. All except the very cold zone are now sub-divided into rainfall regions. The resulting regions all have a distinct climate and these are shown in the map below. The only climatic type shown on this map which is not based on the temperature and rainfall division is the mountain climate. This map shows 18 climatic types in all and you must become familiar with all of them.

The main features of each climatic type are summarised in three or four statements, and a climatic diagram is drawn for a particular town for each type. At least two towns have been selected for each of the tropical climates. The climatic diagrams show:

1 Monthly Rainfall
2 Total Annual Rainfall
3 Mean Monthly Temperature
4 Annual Temperature Range
5 Prevailing Winds
6 Type of Rainfall.



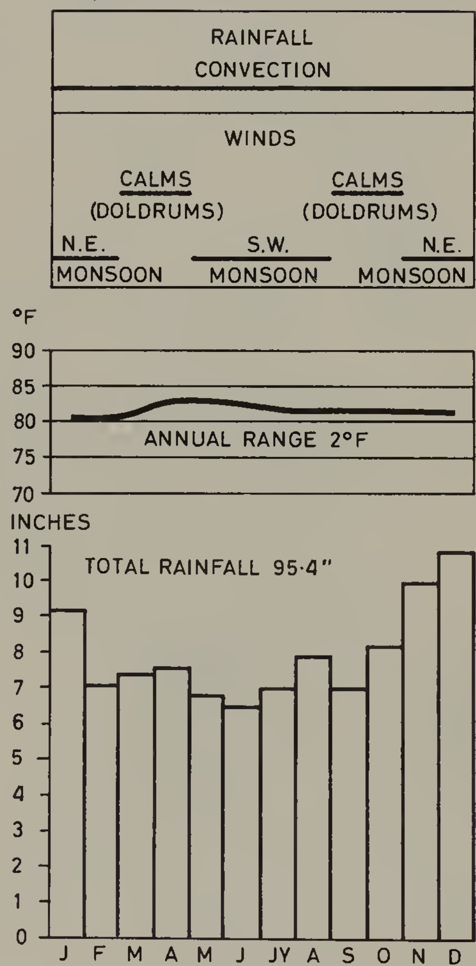
* All parts of this zone have about the same amount of rain.

Hot Climates

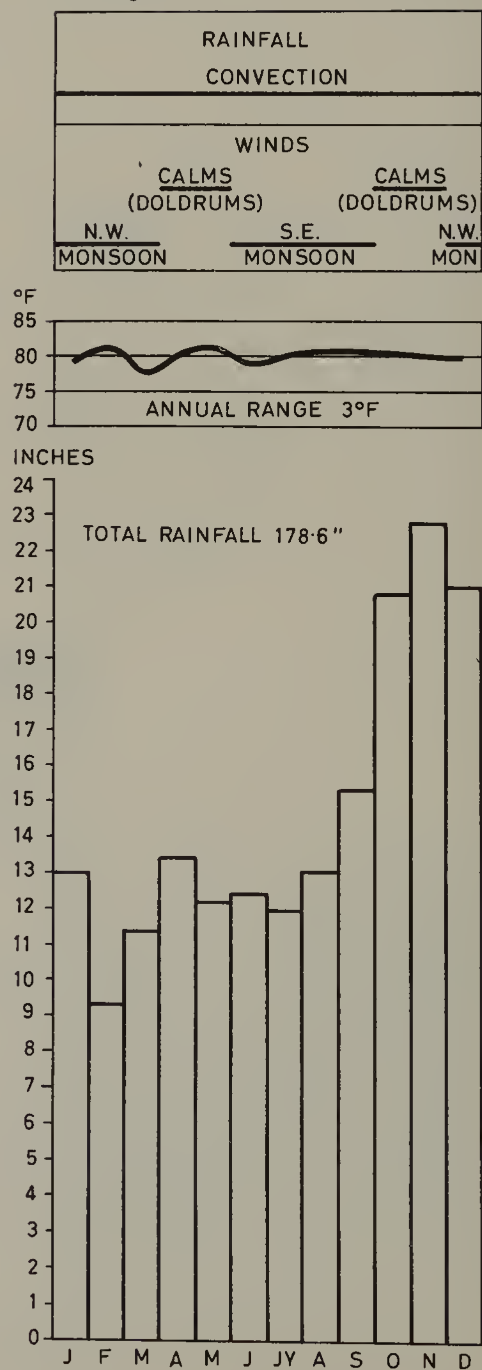
Equatorial Climate (Singapore and Padang)

1 Temperatures are high all the year—during the day they are about 80°F and during the night about 70°F.
2 Cloudy skies prevent the temperatures from rising much above 85°F (in other tropical regions having clear skies the temperatures often rise above 100°F).
3 It rains almost very day during the afternoon when thunderstorms are common.
4 Heavy rainfall and high temperatures result in high humidity.
5 Day and night are almost of equal length, i.e. 12 hours every day of the year.

Singapore



Padang



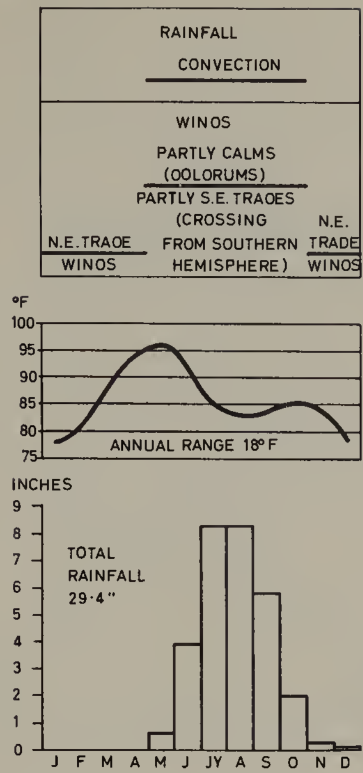
Sudan or Savanna Climate (Kayes and Bulawayo)

1 Temperatures are generally higher than they are for an equatorial climate. During the season when the sun is overhead, daily temperatures are between 90°F and 95°F. For the rest of the year they are between 80°F and 90°F.

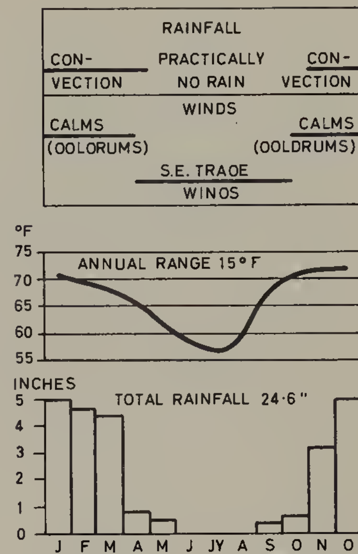
2 Heavy convection rains similar to those of equatorial regions occur daily in the hotter season. During this part of the year the doldrums cover the regions. For the remainder of the year there is little or no rain.

3 During the dry season the trade winds are off-shore. These winds almost cease to blow in the wet season.

Kayes



Bulawayo



Tropical Marine Climate (Havana, Durban and Manila)

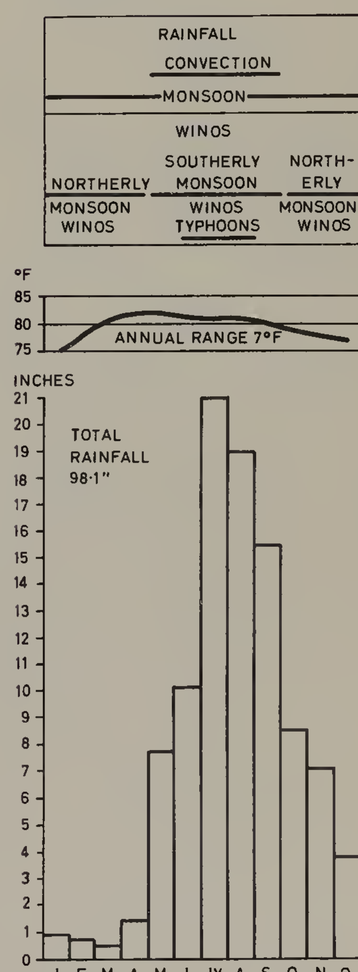
1 Regions having this climate receive on-shore trade winds throughout the year.

2 Temperatures are similar to those for an equatorial region except that the annual temperature range is slightly higher.

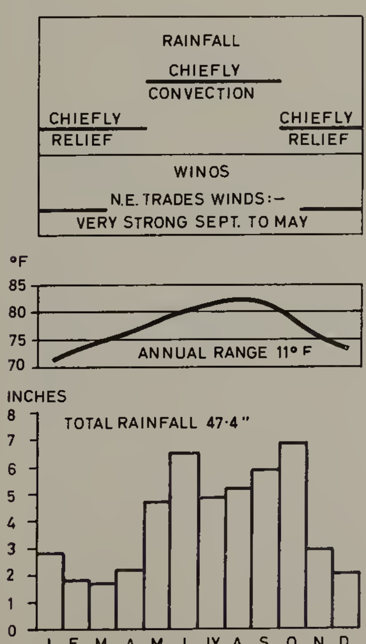
3 The hottest part of the year is when the sun is in the overhead position. This is also partly due to the longer days at this time.

4 It rains almost every day and the total yearly fall is high.

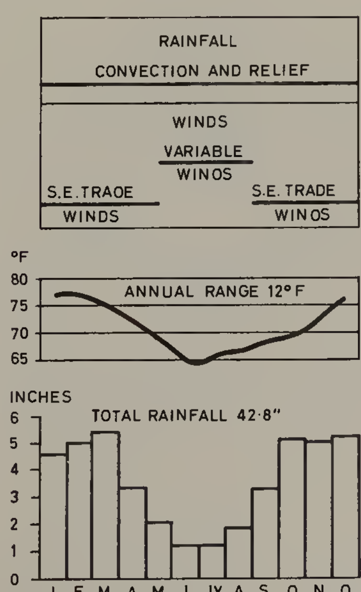
Manila



Havana



Durban



Tropical Monsoon Climate (Delhi, Bombay and Darwin)

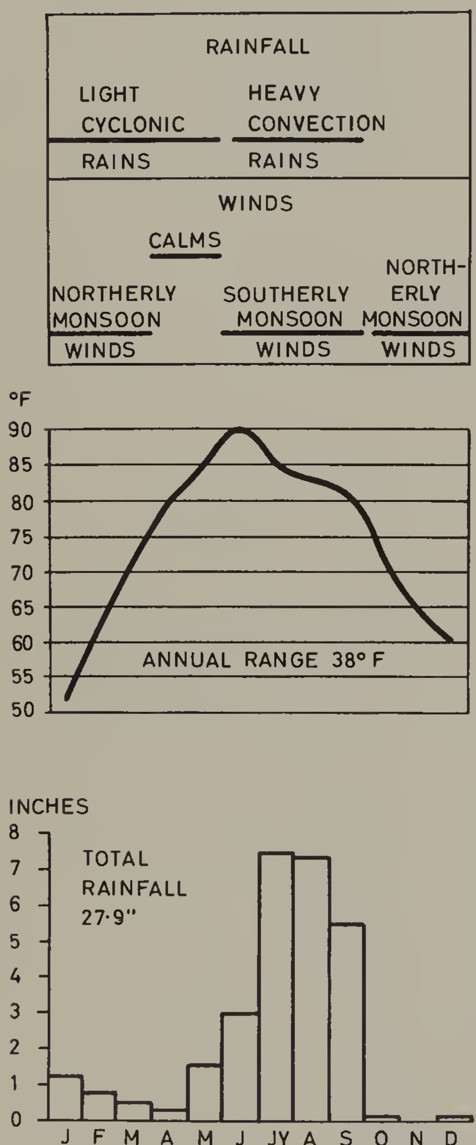
1 The chief feature of this climate is the seasonal reversal of the winds. For one season they are on-shore and they bring heavy rain to coastal regions; for the other season they are off-shore. During this season there is little or no rain.

2 Just before the wet season begins temperatures are at their highest (80°F to 90°F). Temperatures remain high during this season but fall to between 50°F and 70°F during the succeeding dry season.

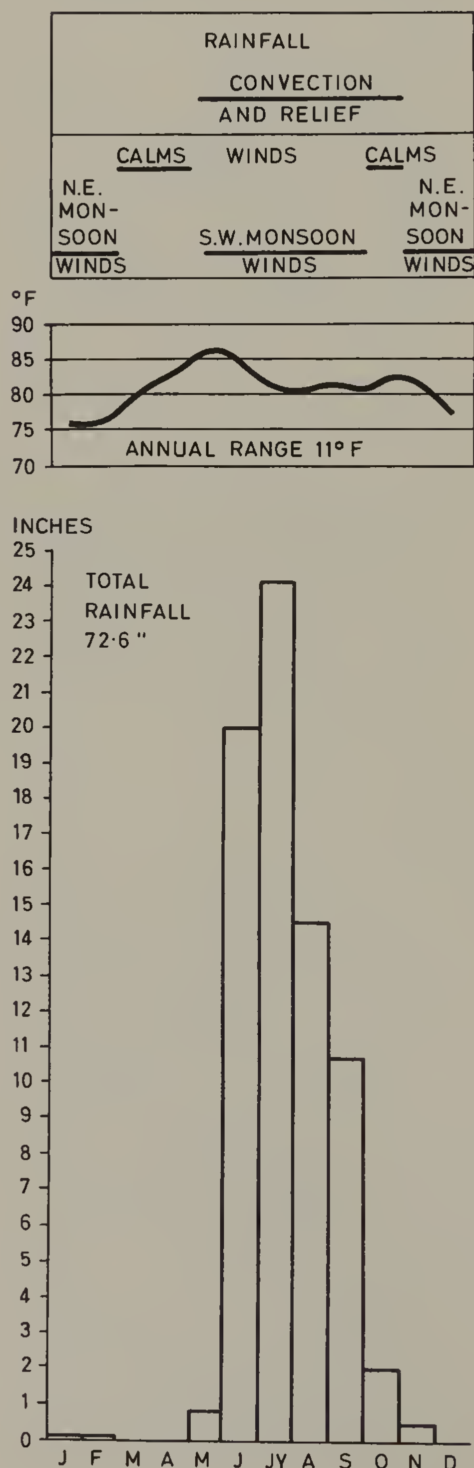
3 In the Indian Sub-continent and Burma there are three seasons:
Oct./Feb.—Cool, dry season
Mar./May—Hot, dry season
Jun./Sept.—Hot, wet season.

Note Cloudy skies in the wet season cause the temperatures to fall (see graphs for Bombay and Delhi).

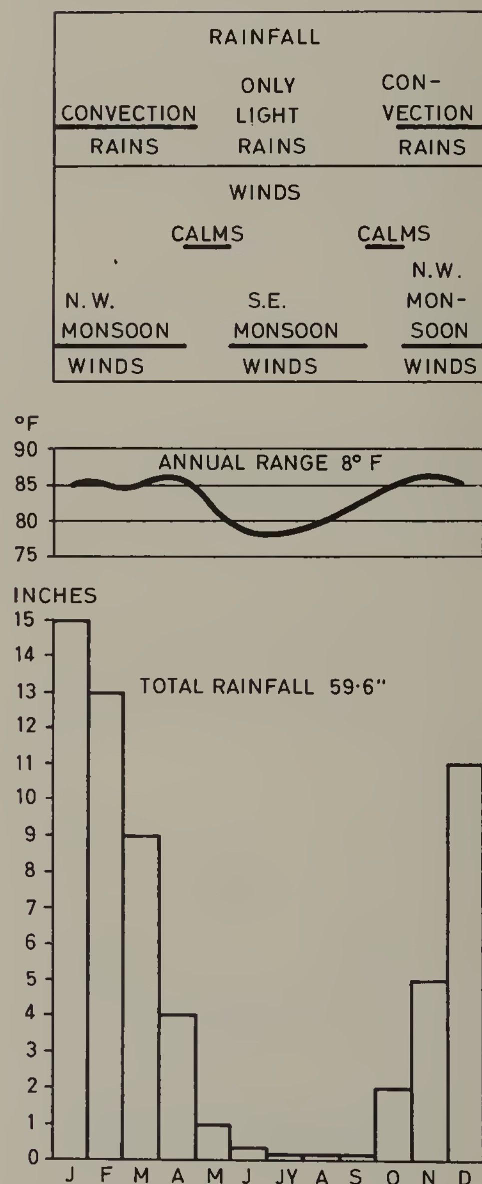
Delhi



Bombay



Darwin



Hot Desert Climate (Antofagasta, In Salah)

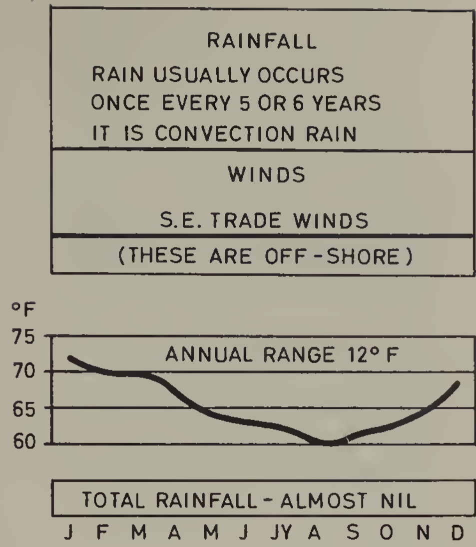
1 Off-shore trade winds blow almost continuously throughout the year. These winds often cross great stretches of land and are therefore not rain-bringing.

2 When the sun is in the overhead position, monthly temperatures are 80°F. This is the hot season. In the cool season temperatures are about 50°F.

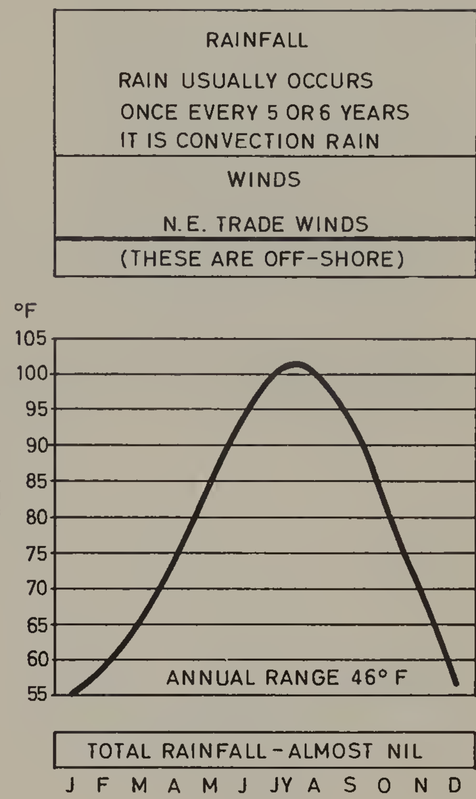
3 Cloudless skies and bare rock or sandy surfaces cause the day temperatures to rise to over 110°F in the hot season. The night temperatures often fall to 50°F or below. This explains why the monthly mean temperatures are not higher than 80°F.

4 Rain falls once every two or three years only. But when it comes it does so as torrential downpours.

Antofagasta



In Salah



Warm Climates

Mediterranean Climate (Sacramento and Perth)

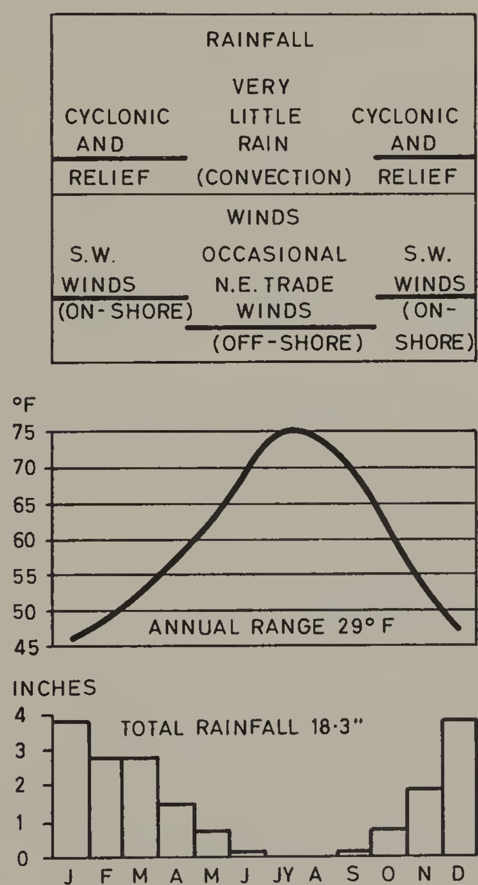
1 The main features of this climate are hot dry summers, mild rainy winters.

2 During the summer monthly temperatures are between 70°F and 80°F; during the winter they range from 42°F to 50°F.

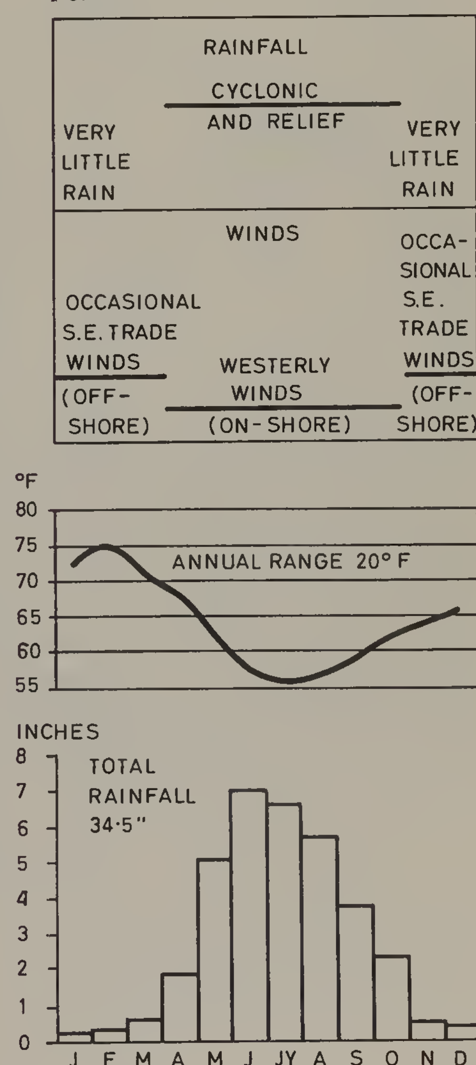
3 On-shore westerly winds blow for most of the winter. They bring depressions from the sea which give rise to cyclonic rain. In mountainous regions the same winds produce heavy relief rainfall.

4 In the summer winds are usually weak and are often off-shore. These are usually called the trade winds. You should remember, however, that westerly winds are by no means uncommon in this season, but because the land is hotter than the sea these winds give rise to very little rain. As the winds pass over the land they warm and tend to absorb moisture rather than yield it.

Sacramento



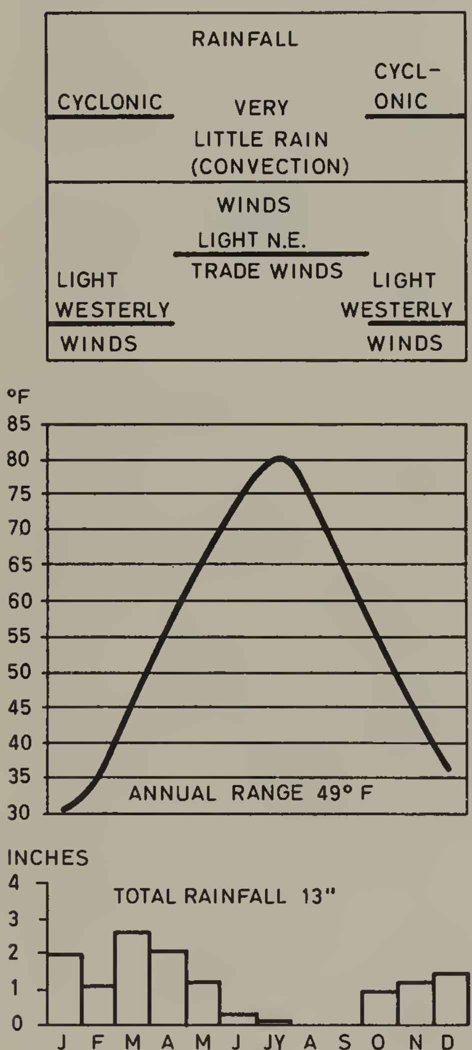
Perth



Temperate Desert Climate (Tashkent)

1 Summer temperatures often rise above 100°F; winter temperatures often fall below 32°F. Great distance from the sea is the chief cause of this pattern.
2 Most of the rain falls in the winter and is brought by depressions carried in the westerly winds. There is little rain in summer. The total annual rainfall is very small.

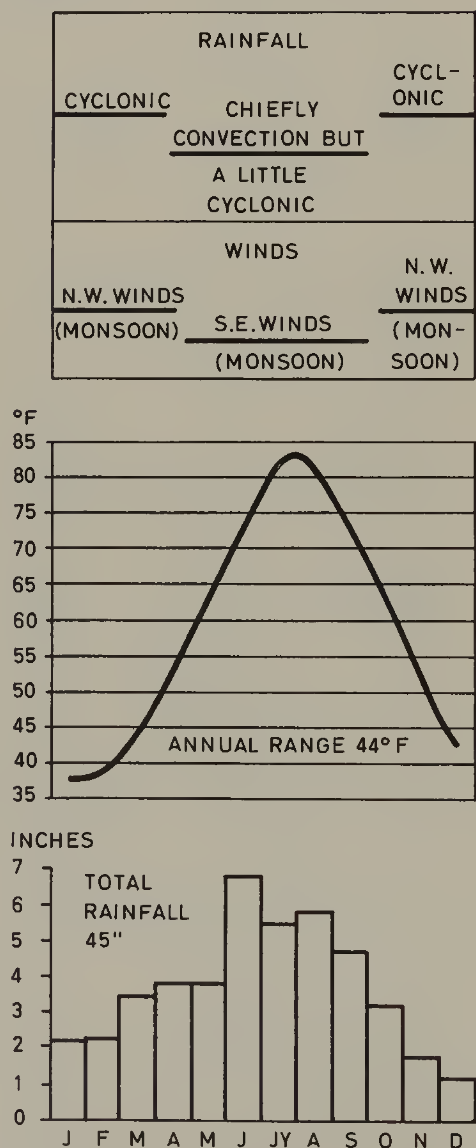
Tashkent



Central China Climate (Shanghai)

1 Winters are cool to cold (35°F–45°F). This is caused by cold winds blowing out from Central Asia. Summers are hot (70°F–80°F).
2 Rain comes throughout the year and is brought by depressions in the winter and by on-shore winds in the summer. There is more rain in summer than in winter. You will see that the wind pattern is monsoonal.
3 Typhoons are frequent in late summer and the autumn.

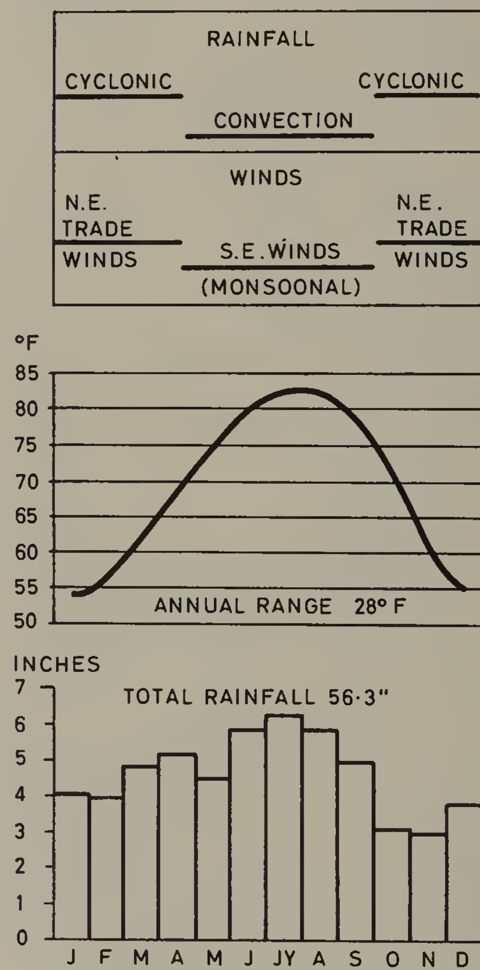
Shanghai



Cotton Belt Climate (New Orleans)

1 Winters are warm (50°F–60°F) and summers are hot (70°F–80°F).
2 Rain comes throughout the year. It is brought by on-shore winds in the summer and by depressions in the winter.
3 Hurricanes are frequent in the autumn.
4 You will see that this climate is similar to that of Central China but remember the differences:
(i) It has warmer winters
(ii) It has more rain.

New Orleans



Cool Climates

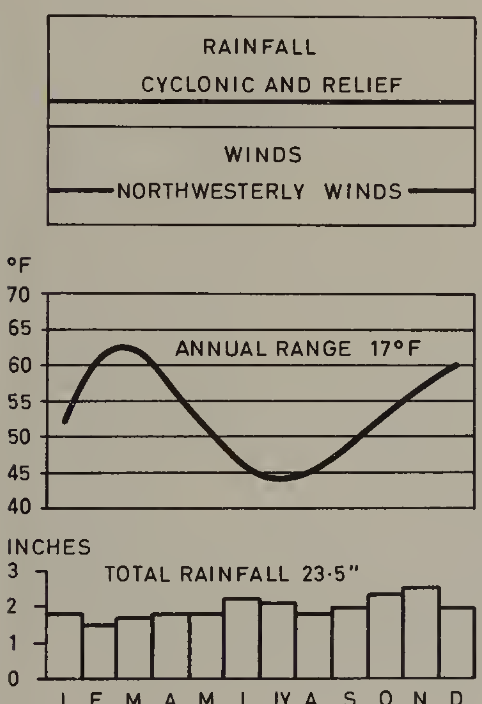
West European Climate (Vancouver and Hobart)

1 Winter temperatures are between 35°F and 45°F. During this season the on-shore westerly winds are warmed by the seas over which they blow. If there were no seas the temperatures would be much lower.
2 Summers are cool to warm (55°F–60°F). Winds are still on-shore, but they are now cooled by the seas over which they blow. Temperatures would be higher if there were no seas.
3 The westerly winds bring rain throughout the year. A large amount of it is brought by depressions in the westerly winds.

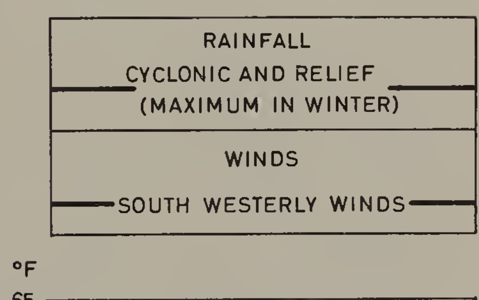
Continental Climate (Moscow)

1 Winters are cold to cool (25°F–35°F); summers are warm (60°F–70°F). There are no nearby oceans to raise the winter temperatures or lower the summer temperatures.
2 Rain falls during the summer and snow during the winter.

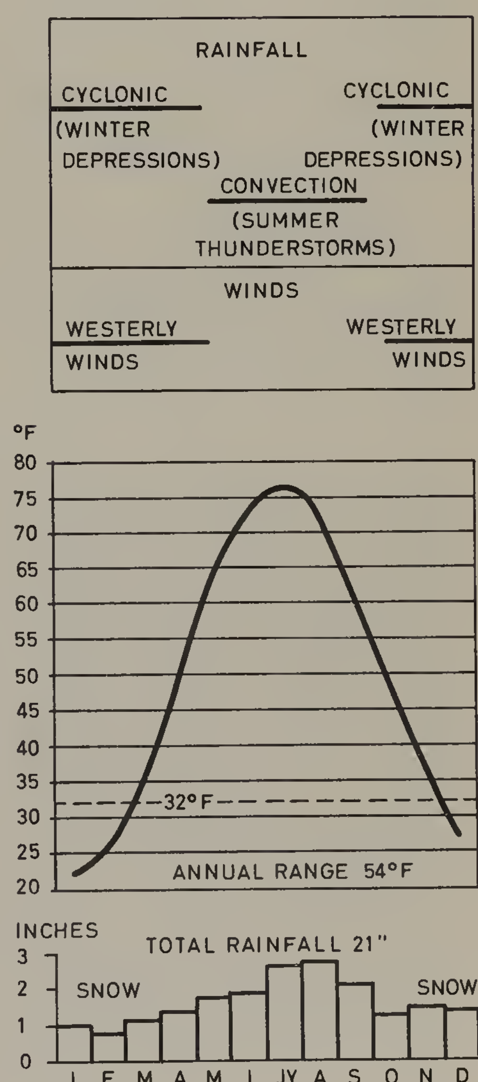
Hobart



Vancouver



Moscow



Laurentian Climate (Montreal)

1 Winters are cold (15°F–35°F); summers are warm (60°F–70°F). Cold winds blowing out from the heart of the continent lower the winter temperatures.
2 Heavy falls of snow occur in the winter. This is because the out-blowing winds pick up moisture from the Great Lakes. Fairly heavy falls of rain occur in the summer.

North China Climate (Peking)

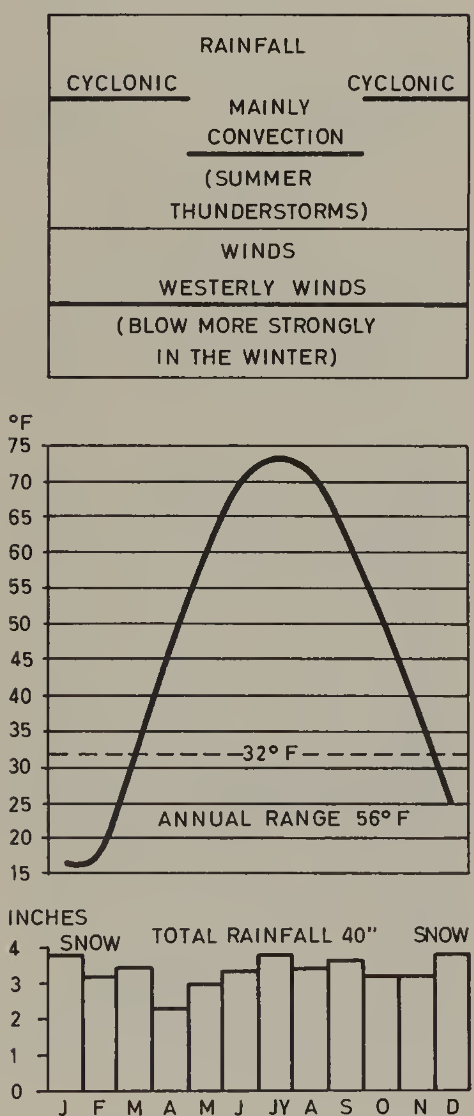
1 Winter temperatures are similar to those of the Laurentian Climate; summer temperatures are a little higher.
2 Rainfall is fairly light (below 30″ per year). Most of this falls in the summer when the winds are on-shore. During the winter the winds are off-shore, and these are dry having crossed a land surface.
3 The seasonal reversal of winds makes this a monsoon climate.
4 This climate is similar to the Laurentian Climate. Remember the differences:
   (i) Much lighter annual rainfall and it comes mainly in the summer.
   (ii) Slightly higher summer temperatures.

Cold Climates

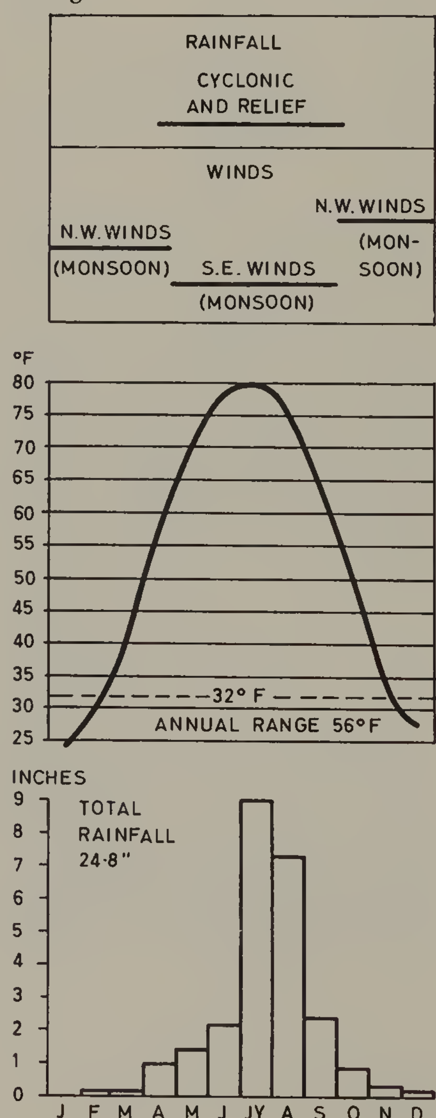
West Margin (Bodo)

1 Winters are long and cold (25°F–31°F); summers are short and cool (45°F–55°F).
2 On-shore westerly winds blow all the year. They bring rain in the summer and snow in the winter.

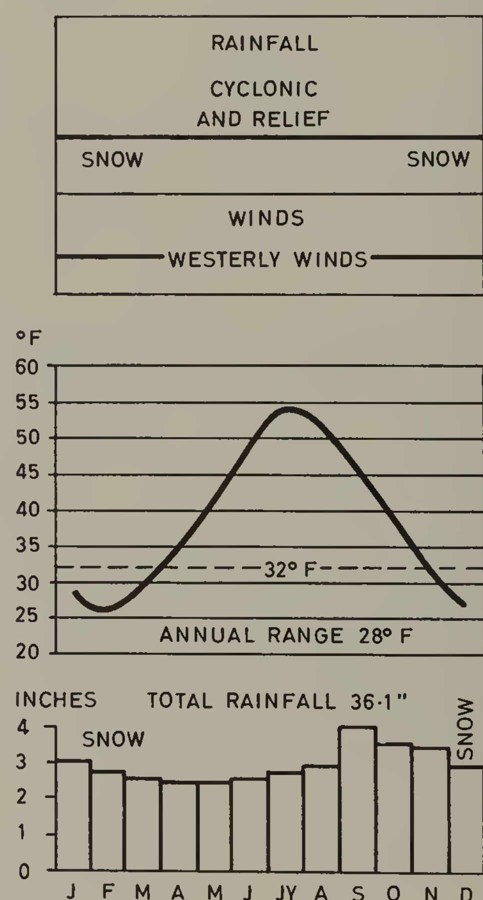
Montreal



Peking



Bodo



Continental (Verkhoyansk)

1 Winters are long and very cold. Temperatures are below 32°F for about 8 months each year and they often fall below −40°F. Summers are short and cool (40°F–60°F).
2 A little rain falls in the summer and there are light falls of snow in the winter.
3 The sub-soils are frozen for most of the year and this makes agriculture very difficult—sometimes impossible.

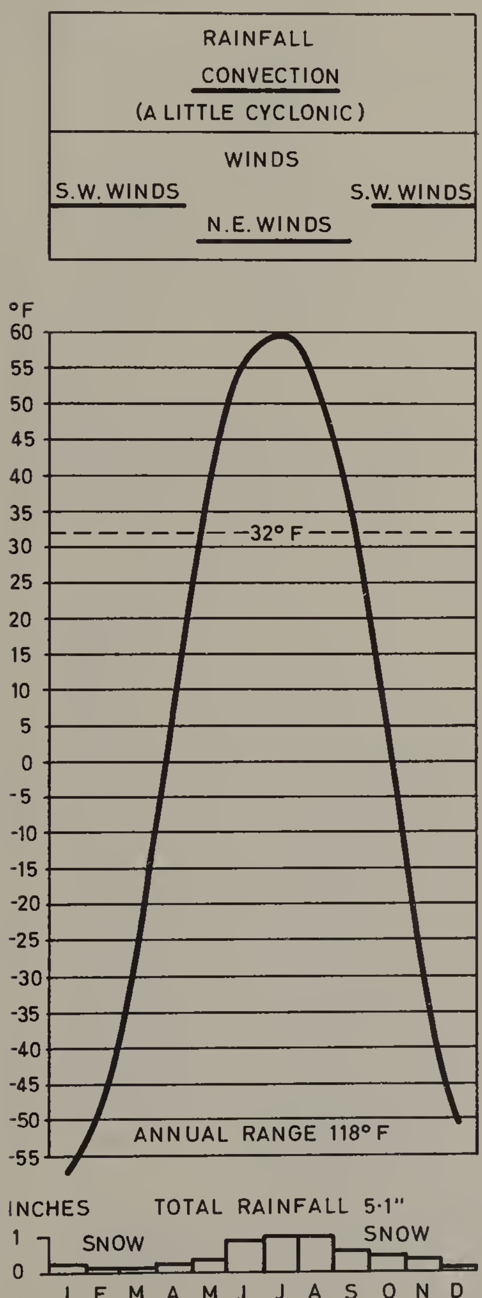
Manchurian Climate (Harbin)

1 Cold winds blow out from the heart of Asia in the winter and temperatures often fall below 0°F. Summers are hot and temperatures usually rise above 70°F. Winters are long and summers are short.
2 On-shore winds in summer bring rain.
3 The seasonal reversal of winds makes this a monsoon climate.

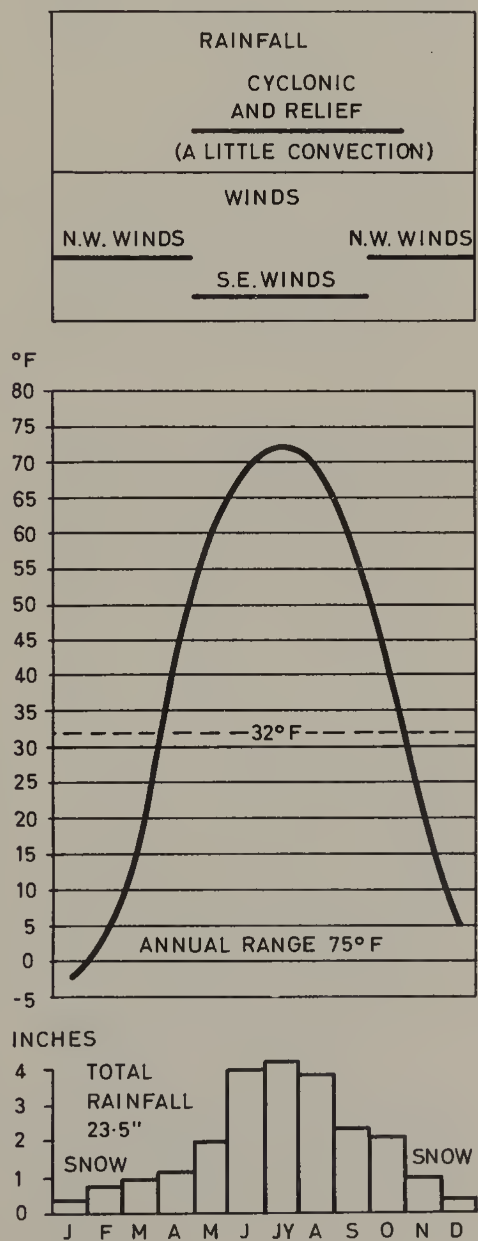
Tundra Climate (Angmagssalika)

1 Winters are long and cold (15°F–32°F); summers are short and cool (40°F–45°F).
2 Fairly heavy falls of snow occur in the winter and light falls of rain in the summer.

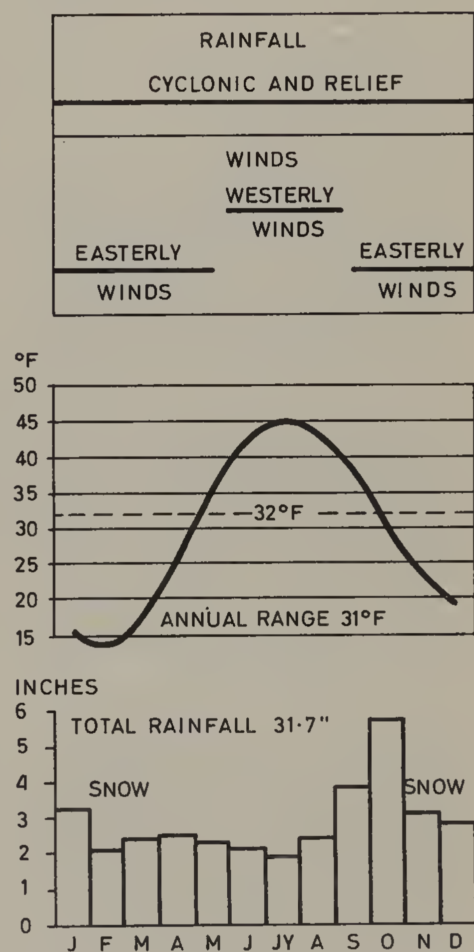
Verkhoyansk



Harbin



Angmagssalika



Chapter 9 Vegetation

Geographers divide the world's vegetation into a number of types according to the appearance of the plants. The basic types, shown in the map on page 153, are:

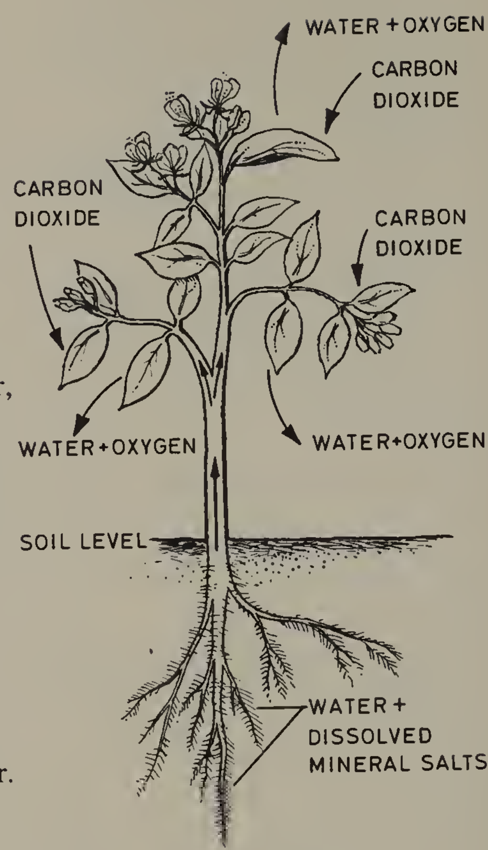
1 Forest 2 Grassland 3 Desert; but before examining these it is important for us to know something about what a plant requires in order to maintain its growth.

Plant Requirements
Green plants make their own food by using:

(i) Water
(ii) Sunlight
(iii) Carbon dioxide
(iv) Mineral salts.

Water with the mineral salts in solution enters the roots of a plant from the soil and passes through the stem into the leaves, where a process called *photosynthesis* goes on. In this process carbon dioxide, which enters the leaves from the air, combines with the water in the presence of sunlight to form carbohydrates (food). The surplus water passes out of the leaves into the air and this movement of water is called *transpiration*. These two processes enable plant-growth to take place. If any of the four requirements are missing or are inadequate then these processes either slow down or cease altogether.

DURING SUNLIGHT



The Influence of Temperature and Water on Plant-growth
Temperature and water are the two most critical plant requirements because they do not occur in adequate amounts in all regions, and in some they vary in amount from season to season.

Plant-growth normally ceases when the temperature falls below 43°F. In polar regions the temperature is always below 43°F and there is no plant life. In other regions the temperature is always above 43°F and continuous plant-growth is possible. In still other regions the temperature is below 43°F for one season and above it for another season. Plant-growth is therefore seasonal.

Plants, like animals, have become adapted to their physical environment, in particular to the water and temperature aspects of this. Because water and temperature vary from natural region to natural region, the plants also vary in size and form. Thus hot wet regions normally have a forest vegetation whereas regions having light seasonal rains usually support a grass vegetation. Generally speaking, trees require more water than do grasses which in turn require more than desert plants. We need not examine all the ways in which plants have adapted themselves to their environments, but we must have a look at the influence of drought and cold on plant adaptation.

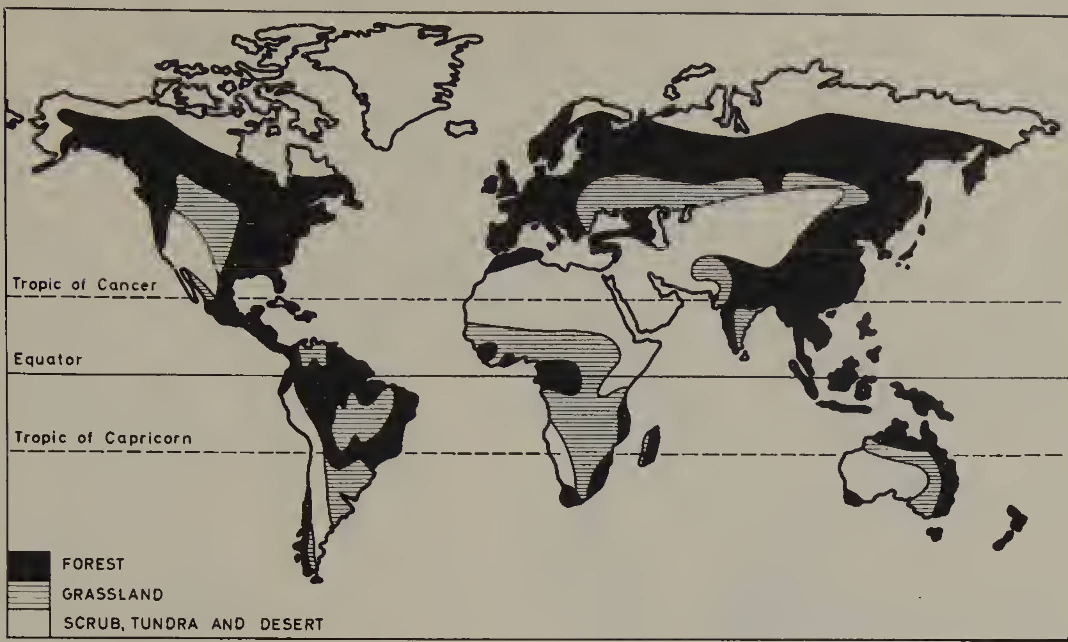
Influence of Drought on Plants

1 Some plants develop long roots to reach water supplies far below the surface.
2 Some plants develop water storage organs, e.g. the *baobab tree* stores water in its trunk.
3 Some plants have special leaves which reduce transpiration, e.g.
   thorn-like leaves;
   rolled-up leaves;
   leaves with waxy surfaces.
4 Some plants shed most of their leaves when the dry season is also hot. If the plants did not do this then they would literally dry up as transpiration proceeded. Monsoon forests are almost leafless in the dry season.

Influence of Cold on Plants
When temperatures fall below 43°F for several months of the year, many plants are unable to obtain sufficient water from the soil and many of them shed their leaves. Such plants are said to be *deciduous*. This reaction to cold is particularly common in temperate forests.

Note Some trees have become adapted to cold weather and do not shed their leaves. *Coniferous trees* (except larch) keep their leaves throughout the cold season and they are called *evergreen* trees. They are able to do this because:

(i) their leaves are rolled and little transpiration takes place from them.
(ii) they need less water than other trees.



Types of Natural Vegetation

The map on page 154 shows the basic types of natural vegetation. This map gives a very simplified picture of the vegetation pattern, and so does the map on page 155, although this map shows more detail. It would appear from these maps that natural vegetation covers the entire land surfaces of the earth, but, of course, this is not so. Extensive lowland regions have long since been cleared of their vegetation to make way for man's crops and settlements. These maps are intended to show what the natural vegetation pattern would be like if man and his animals had in no way interfered with the land. Natural vegetation is only extensive today in those parts of the world where man finds great difficulty in mastering the environment, e.g. the arctic lands and the equatorial river basins.

We will now examine these basic vegetation types. For each type we must know the location and the names of some of the more common plants together with the way in which these plants have adapted themselves to the climatic characteristics.

The Forests

I Tropical Evergreen Forest

Location Amazon and Congo Basins; West African Coastlands; Malaysia; Coastal Burma, Cambodia and Vietnam; most of Indonesia and New Guinea.

Appearance

1 Contains a great variety of plants which are close together.

2 The forest consists of three layers:
- (a) *top layer:* tall trees with buttress roots;
- (b) *middle layer:* tree ferns, lianas, e.g. rattan, and epiphytes, e.g. orchids;
- (c) *bottom layer:* ferns, herbaceous plants and saprophytes.

3 Nearly all the trees are broad-leaved evergreens because high temperatures and evenly distributed rainfall permit growth throughout the year.

4 Absence of seasonal climatic change results in some plants being in flower, others in fruit and others in leaf-fall at one and the same time.

5 The leaves of the tall trees form an almost continuous canopy which shuts out most of the light at ground level. There is therefore little undergrowth.

Examples of trees — *Mahogany*, *ebony*, *rosewood*, *ironwood* and *greenheart* are common trees. *Palms* and *tree ferns* also occur in most equatorial forests. These trees, as well as most of the other plants, occur singly or in small groups. There are rarely extensive stands of a particular tree.

II Tropical Monsoon Forest

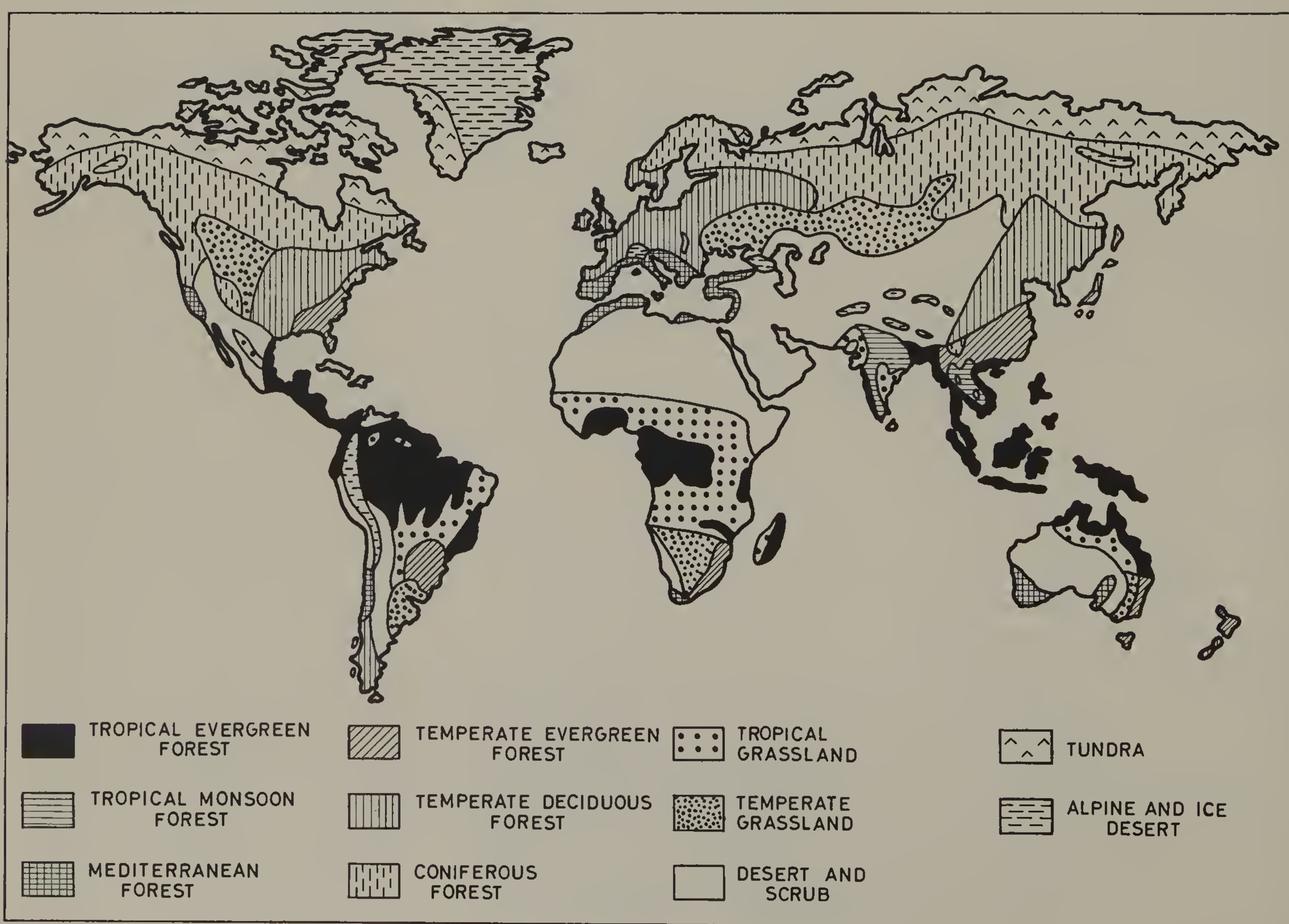
Location — Burma; Thailand; Cambodia; Laos; N. Vietnam; parts of India; East Java and the islands to the east; N. Australia.

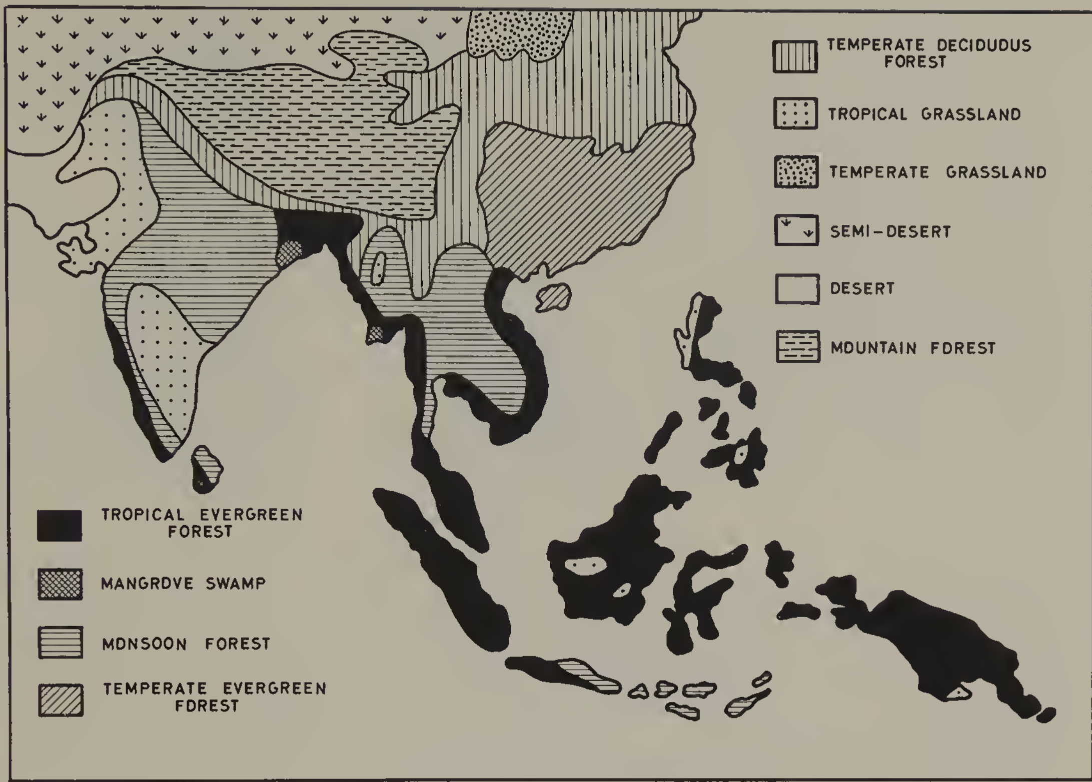
Appearance

1. Because of a marked seasonal drought the trees are deciduous (some trees are semi-deciduous).
2. During the wet season the forest looks much like an equatorial forest, although there is more undergrowth because the trees are spaced farther apart and more light reaches the ground than in an equatorial forest.
3. These forests merge into typical equatorial forests in regions where the dry season becomes short or non-existent, and into grasslands in regions where the wet season becomes short and rainfall less heavy.

Examples of trees — *Teak* (especially in Burma, Thailand, Cambodia, Laos and E. Java); *bamboo* (especially in Thailand, Cambodia, Laos and Vietnam); *sal*; *sandalwood*; and *lianas*. *Acacia*, *eucalyptus* and *casuarina* occur in E. Java and N. Australia.

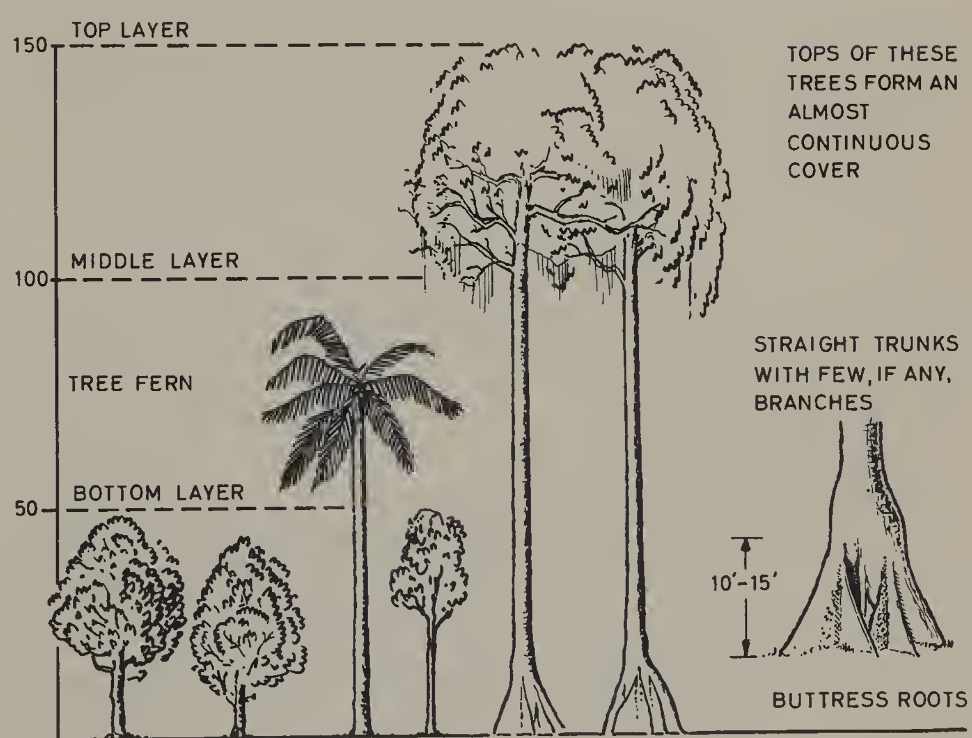
Natural Vegetation—the World





The diagram shows the three layers of vegetation in an equatorial forest. Many of the tall trees have buttress roots which give them support (remember they are of great height). Trees with buttress roots also occur in monsoon forests.

Structure of an Equatorial Forest



III Temperate Evergreen Forest

Location This occurs chiefly on the eastern sides of land masses in the warm temperate latitudes. S. China; S. Japan; S.E. Australia; North Island (New Zealand); Natal coastlands (Africa); S. Brazil, and S.E. states of U.S.A.

Appearance
1 Because these regions have no dry season most of the trees are broad-leaved evergreen hardwoods.
2 There is a great variety of trees, and in some regions, e.g. Florida, the trees are covered with lianas.
3 The forests look very much like tropical forests in that the vegetation is thick and profuse.

Examples of trees *Evergreen oak*; *magnolia* (especially China and U.S.A.); *camphor* and *bamboo* (especially China); *cedar*, *maple* and *walnut* (especially U.S.A.); *eucalypts* (Australia); *tree fern* (New Zealand); *mulberry* (China); and *cypress* (U.S.A.).

IV Mediterranean Evergreen Forest

Location This occurs chiefly on the western sides of land masses in the warm temperate latitudes. Lowlands around the Mediterranean Sea; S.W. Australia and the Adelaide District of Australia; S.W. Africa; Central Chile; Central California.

Appearance
1 The trees are widely spaced and are better called a woodland than a forest.
2 Although these regions have a dry season many of the trees have become adapted to this and remain evergreen.
3 In the drier parts the vegetation becomes scrub-like and consists of sweet-smelling herbs such as lavender.
4 In the wetter parts, e.g. on mountain slopes, coniferous trees become common.

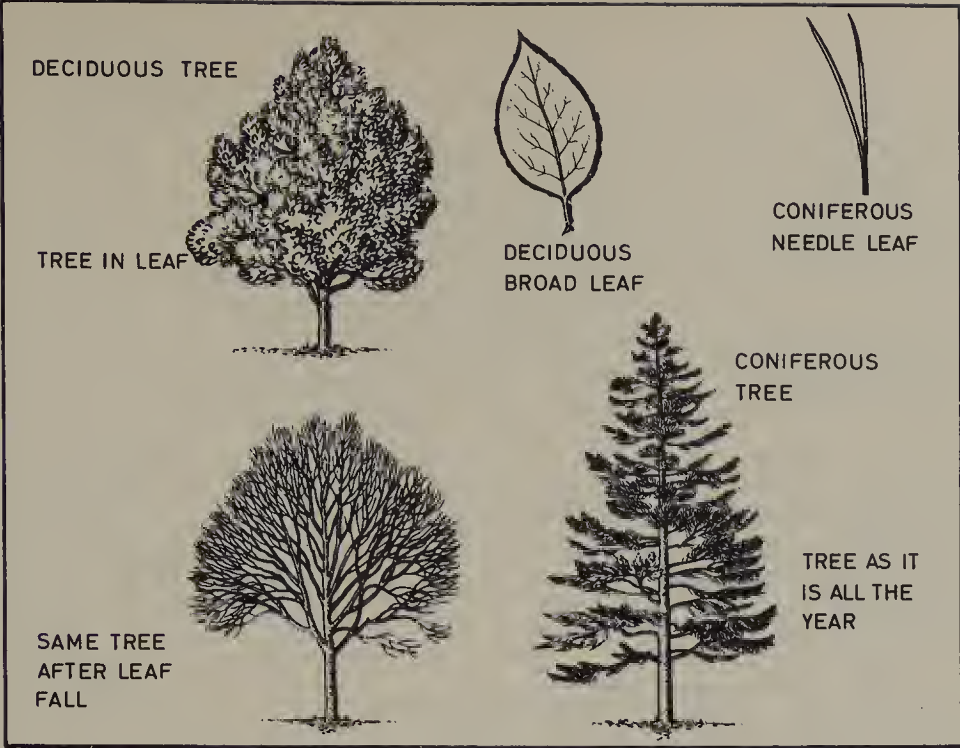
Examples of trees *Evergreen oak*; *cork oak*; *eucalypts*, *jarrah* and *karri* (S.W. Australia); *cedar* and *cypress* (both are conifers), and *sequoia* or redwood (California). The scrub vegetation which includes *lavender*, *rosemary*, *myrtle* and *oleander* is a secondary type of vegetation, i.e. it has arisen in consequence of the destruction of the original vegetative cover. In France this is called *maquis*; and in California *chaparral.*

V Temperate Deciduous Forest

Location W. and Central Europe; Eastern U.S.A.; N. China; N. Japan; Korea; S. Chile and South Island (New Zealand). The forest is poorly developed in S. Chile because of the high relief.

Appearance Being located in a cool temperate latitude, the winters are sufficiently cold to cause the trees to be deciduous. During the winter most of the trees are completely bare of leaves (diagram page 157).

Examples of trees *Oak*; *beech*; *hazel*; *elm*; *chestnut*; *poplar*, and, in N. America, *walnut*; *maple*; *hickory*; *cedar* and *spruce*.



VI Coniferous Forest

Location — This is most extensive in high latitudes and on high mountains, although it does develop on sandy soils in warmer regions. There are two main belts of this forest: (i) across Eurasia extending from the Atlantic to the Pacific, (ii) across N. America extending from coast to coast.

Appearance — Nearly all the trees are evergreen, their needle-shaped leaves being adapted to the cold winters (see diagram). There is practically no undergrowth in the forest because the soil is frozen for many months each year. Small shrubs like bilberry, cranberry and mosses and lichens develop.

Examples of trees — *Hemlock*, *spruce*, *pine* and *fir*. The trees of coniferous forests in Mediterranean regions are chiefly *cypress* and *cedar*.

The Grasslands

I Tropical Grassland

Location — These are located mainly in the continental regions of tropical latitudes, where the rains occur in the hot season which lasts for about 5 months. *North and south of the Congo Basin*, *West Africa* and the *East African Plateaus*; parts of *Brazil*; the *Guiana Highlands*; *north and east of the Australian Desert*; and parts of the *Indian Deccan Plateau*.

Appearance

1. The true grasslands consist of grasses over 6 ft. high. Where the grasslands merge with equatorial forest, trees become more and more numerous. Where they merge with the hot desert the grass becomes discontinuous and scrub-like, e.g. *Mallee*[1] and *Mulga*[2] of Australia.
2. During the dry season most of the grasses turn yellow and 'burn' up.
3. During the wet season the grasses grow up quickly and form a green mantle.

1. *Mallee*—eucalyptus bushes set in a thicket of coarse grass.
2. *Mulga*—clumps of acacia set in a thicket of coarse grass.

4 Some trees such as the *baobab* survive the long dry season by storing water in their swollen trunks.

5 Trees are usually umbrella-shaped.

Grassland names Tropical grasslands have different names according to their location, e.g. *Campos* (Brazil); *Llanos* (Guiana Highlands); *Savanna* (Africa and Australia).

II Temperate Grassland

Location These are best developed in the continental interiors of temperate latitudes, e.g. hearts of *Asia* and *N. America*. Less extensive areas occur in *S. Africa*, *S. America* and *Australia.*

Appearance There is a continuous cover of short tufted grass which is green in summer and brown in winter. A few trees line the banks of streams and rivers.

Grassland names The following names are generally recognised: *steppe* (Eurasia); *prairie* (N. America); *pampas* (Argentina); *veld* (S. Africa); *downs* (Australia).

Note In most of the grasslands the leaves of the grasses wither and die in the dry season (tropics) or cold season (temperate regions). The roots of the plants however do not die, and, in the following season when the rains come, the aerial parts of the plants grow afresh.

Giant Cactus from the Sonora Desert—Mexican Border with U.S.A.

Desert and Semi-desert

I Tropical Desert

Location — Usually lies between 15° and 30° N. and S. They lie on the western sides of land masses except for Africa where they extend from coast to coast, linking up with the Asian deserts. The chief regions having a desert vegetation are: *Sahara* (N. Africa); *Arabia*; parts of *Iran*, *Iraq*, *Syria*, *Jordan* and *Israel*; part of *W. Pakistan*; *Central Australia*; *Kalahari* (S. Africa); *Atacama* (coastal Peru and N. Chile), and *S. California*, *N. Mexico*, parts of *Arizona* (N. America).

Appearance and examples of plants
1 Only small areas are without vegetation of any type.
2 All the plants are adapted to drought and a high rate of evaporation (deep roots, thick bark, spiky leaves or just thorns). Many plants produce seeds which lie dormant for years until a little rain falls and then they germinate.
3 Tufts of coarse grass, cacti and thorn bushes, e.g. acacia, form the chief plants.

II Semi-desert and Scrub

Location — This type of vegetation occurs in regions which either border the tropical deserts, or in the interiors of continents where the rainfall is just insufficient to maintain a continuous cover of vegetation.

Appearance and examples of plants — In tropical scrubland the chief plant is the thorny acacia. During the period of rains a short-lived but rich mantle of grasses and flowering plants covers extensive areas. Sage bush is common in N. American scrubland. Mulga is sometimes included in this vegetation type.

III Tundra

Location — This type of vegetation is chiefly confined to the Northern Hemisphere, fringing the Arctic Ocean in the continents of Eurasia and N. America.

Appearance and examples of plants
1 The growing season is very short (about two months), and at this time the surface soil thaws but the subsoil remains frozen. Water therefore lies on the surface. This influences the pattern of vegetation.
2 Where the tundra meets the coniferous forest there are stunted willows and birches.
3 Most of the tundra consists of a low cover of vegetation made up of lichens, mosses, sedges, and flowering shrubs such as bilberry and bearberry.

Chapter 10 Soils

General

Weathering processes break up the surface of a rock into small particles. Air and water enter the spaces between these and chemical changes take place which result in the production of chemical substances. Bacteria and plant life soon make their appearance. When the plants die, they decay and produce *humus* which is all-important to soil fertility. Broadly speaking, humus consists of the decayed remains of both plants and animals. Bacteria play a vital part in the decomposition of these remains. The end product of these chemical and biological processes is *soil*. From this it will be clear that the nature of any soil is influenced by:

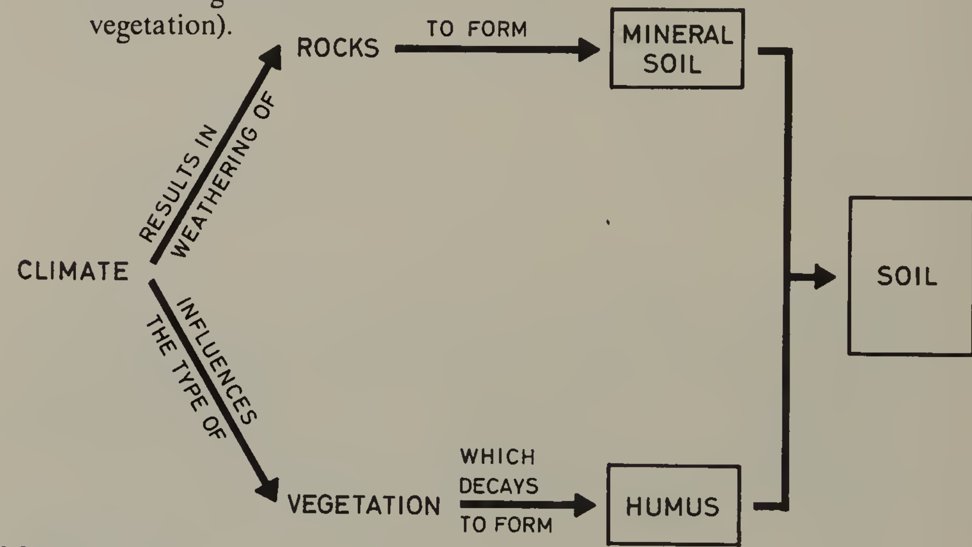
(i) *weathering*
(ii) *vegetation*
(iii) *climate* (this is especially important because it determines both the type of weathering and the natural vegetation).

Contents of the Soil

All soils contain:

(i) mineral particles (inorganic material)
(ii) humus (organic material)
(iii) water
(iv) air
(v) living organisms, especially bacteria.

The actual amounts of each of these depend upon the type of soil. Many soils are deficient in one or more of these.



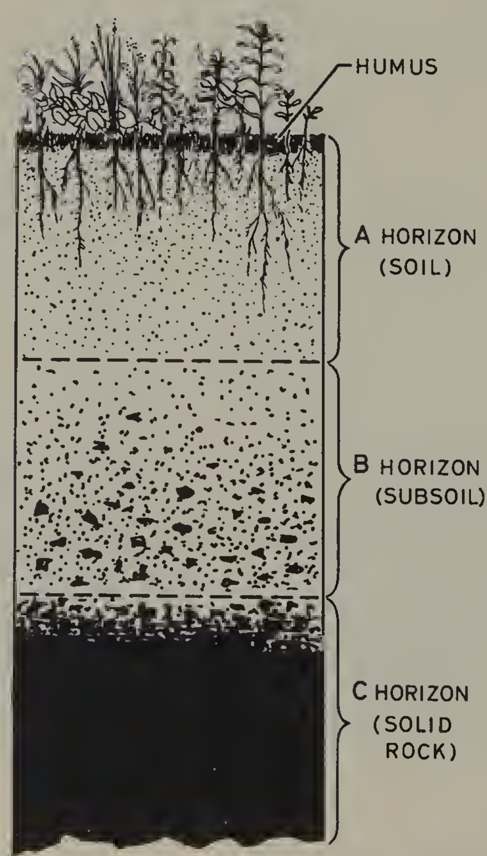
Soil Profile

A soil profile is a vertical section through the soil to the underlying solid rock. Most soil profiles consist of three layers which are called horizons. These are lettered A, B and C.

Horizon A—the soil proper
Horizon B—the sub-soil
Horizon C—the solid rock.

You will see from the lower diagram that the top part of the A horizon is often rich in humus, and that the texture of the soil becomes coarser as the C horizon is approached.

SOIL PROFILE



Factors Influencing the Soil Profile

Water Movement in the Soil
When rainfal! is greater than evaporation water moves downwards in the soil and mineral matter is removed from the top layer (A horizon) and is deposited in the layer beneath (B horizon). Very often these deposits give rise to a hard layer which is called a *hardpan* and this can cause drainage to be poor. When this takes place in a soil the soil is said to be leached. In cold wet regions leaching helps to produce a grey soil which is known as a *podzol*; in hot wet regions it produces a red-brown soil which is known as laterite.

Laterite
In humid tropical regions soil water contains very little organic matter, and such water does not dissolve iron and aluminium hydroxides. Most other minerals however dissolve and these are carried in solution to the B horizon where they are deposited. Ultimately a soil is formed which is composed mainly of *iron* and *aluminium compounds*. This is called *laterite*. This is usually red in colour and becomes extremely sticky when wet. It is a useful material for making bricks since it sets hard on drying. Because it is the end product in the process of weathering, it is almost completely resistant to further weathering and buildings made of it last for a very long time. Some laterites are very rich in aluminium compounds and are called *bauxite*. Bauxite deposits are usually white or grey in colour. Hardpans also occur in laterites.

Note Laterite can form any type of rock.

In hot desert and semi-desert regions there is an upward movement of water in the soil. This results in the deposition of mineral matter in the A horizon. Some of the important deposits of saltpetre have been formed in this manner.

Classification of Soils

Climate plays the greatest part in the formation of a soil (top diagram, page 160), and any classification of soils therefore tends to have a climatological basis. This means that each major soil type corresponds with a specific type of climate. These types are called *zonal soils*. They generally occur in extensive belts and they are mature soils.

Zonal Soils

A *Tropical*
- (i) Laterite
- (ii) Red Soils
- (iii) Black Soils
- (iv) Desert Soils.

B *Temperate*
- (i) Podzols
- (ii) Chernozems (Black Soils)
- (iii) Brown Soils
- (iv) Desert Soils.

For laterite, tropical red soils and tropical desert soils see notes above.

Tropical Black Soils

This type of soil develops in humid tropical regions which have volcanic rocks. The soil is rich in calcium carbonate and other minerals, and when wet it becomes very sticky. It occurs extensively in *N.W. Deccan* (where it is cultivated for cotton), and in smaller areas in *N. Argentina*, *Kenya* and *Morocco*. In the Deccan it is called *Regur*.

Chernozems

These are probably the richest soils in the world. They form under a natural vegetation of grass in the temperate latitudes and are rich in humus. This is because there is very little leaching. Most of the world's wheat is grown on these soils.

Temperate Brown Soils

These soils formed in climatic regions which had a natural vegetation of deciduous forest. The soils are rich in humus, though since much of the forest has now been removed for agriculture, manures have to be applied to the soils to maintain the organic content.

Temperate Desert Soils

The soils of arid temperate regions have not been leached. They are therefore rich in plant foods, and, if irrigated, they are often very fertile. The soils are grey to brown in colour and they occur chiefly in the U.S.S.R. (between the Caspian Sea and Lake Aral), and in parts of West U.S.A.

Other Soils

(For podzols see notes above.)

There are other soils which are less influenced by climate than the zonal soils. These cannot be discussed in any detail here, but the names of some of the more important will be given.

Peat Soils: they form where drainage is very poor, e.g. swamps. Vegetation does not properly decay.
Alluvial Soils: they consist of a mixture of clay, sand and silt which has been deposited by water. They form some of Asia's most important agricultural regions.
Terra Rossa Soils: These are red soils which form in limestone regions under semi-arid conditions.
Wind-deposited Soils: the chief of these is *loess*.

Soil Erosion

Soils and Agriculture

Farmers are not generally interested in soil profiles and soil classification such as we have just discussed. What chiefly interests them is whether the soil is fertile or not. In many regions farmers have learnt how to keep the soil fertile, or to make it more fertile by adding manures, or growing different crops in rotation. But this practice is by no means universal. Soils will deteriorate if they are not properly cultivated, and soil deterioration usually results in the removal of soil by wind or water. When this happens soil erosion is said to take place.

Causes of Soil Erosion

Soil erosion is initially caused by the action of Man and his domestic animals. Most of it begins with the removal of the natural vegetation, be it grass or forest. So long as the vegetation cover remains, there can be little if any erosion because the roots of the plants bind the soil particles together, and the vegetation itself protects the soil from the action of wind and rain. The destruction of the natural vegetation may be caused by turning the land into crop land or by putting too many domestic animals on it which results in over-grazing.

Types of Soil Erosion

I *By Water*

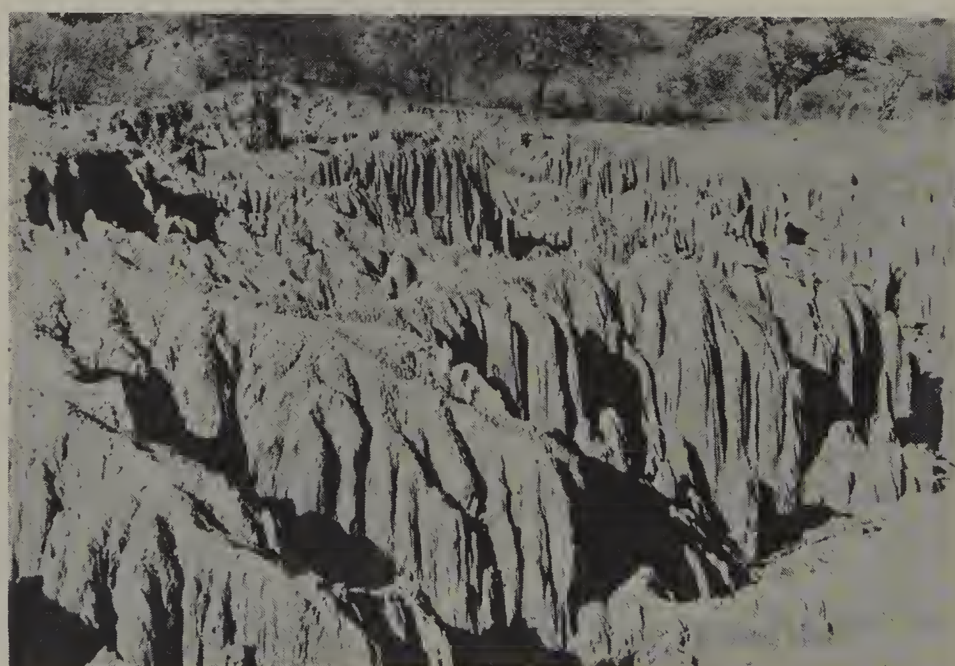
(i) *Sheet Erosion*

This affects large areas and it occurs when rain falls on a slope which is bare of vegetation. This type of erosion results in the removal of a uniform depth of soil. The top photograph below shows the nature of sheet erosion in woodland. You will see that the land is by no means bare of vegetation in this example.

(ii) *Gully Erosion*

This is more localised and occurs when heavy rainfall rushes down a slope, cutting deep grooves into the land. The grooves become deepened and widened to form gullies which finally cut up the land to give 'badlands'. This type of erosion is especially frequent in semi-arid regions.

Sheet Erosion in South Africa



Severe Soil Erosion at Ceara, Brazil

Gully Erosion in Kenya
This photograph shows the force of soil erosion. Some idea of the depth to which erosion has taken place can be obtained from the height of the trees.

II *By Wind*
Regions having a low rainfall or a definite dry season are liable to have their soils reduced to dust and blown away by the wind if the land is bare of vegetation. We have already seen how the wind removes fine particles of material in desert regions by the process of deflation. The same process also take place in the marginal zones of some of the temperate grasslands which have had the grass vegetation replaced by crops such as wheat, or which have been over-grazed by cattle. In these marginal zones rainfall is not only lower than in the grasslands proper, but is also less reliable. Sufficient rain may fall for a few years to enable the crops to

Part of the 'Dust Bowl' in the U.S.A.

thrive but this is inevitably followed by a series of drier years when the crops fail and the land is abandoned. It is at this time, when the land is bare, that wind erosion sets in. One of the worst cases of such erosion occurred in the 1930s in the Mid-western States of the U.S.A. The area devastated here is called the 'Dust-Bowl' (see photograph).

Common Farming Practices which lead to Soil Erosion

1 The cultivation of crops in regions which do not have a reliable rainfall, i.e. dry years following wet years, and which have only just sufficient rainfall for crop farming.
2 The ploughing of land up and down the slope. This provides man-made channels which can be enlarged into gullies by surface run-off.
3 In shifting cultivation (see photograph, page 165) a piece of forest is destroyed by fire, and crops are grown in the soils of the cleared patch which are now enriched by wood ash. After one or two years of such cultivation, the patch is abandoned and a new clearing is made. The abandoned patch soon experiences soil erosion by rainfall. Shifting cultivation usually takes place in the wet tropics. It is a common method of crop farming with wandering forest peoples.
4 The cultivation of the same type of crop on a piece of land year after year, leads to soil depletion if manures or fertilisers are not used. Most plants usually make a demand on a particular mineral compound and if the same type of plant is grown over a number of years then the soil will become deficient in this mineral. When this happens the soil deteriorates and soil erosion may set in.
5 The cutting down of forests, especially on the higher slopes, may result in soil erosion and the spreading out of the transported soil over the lowlands where farm land can be seriously damaged. The lower photograph on page 165 shows the sort of damage that occurs when the transported soils are deposited in built-up areas.

Regions where Soil Erosion takes place

Wind Erosion
Mid-western States of the U.S.A. The eroded region is called the *Dust Bowl*.

Water Erosion
The Mediterranean countries. It is caused by over-grazing by the goat especially in the Eastern countries. Destruction of forests in Spain and parts of Italy has caused erosion.

Parts of India, Ceylon, Sumatra, Java and Thailand. Caused mainly by shifting cultivation.

The Savanna regions of Africa. Caused by shifting cultivation and over-grazing.

Shifting Cultivation in Chile

Deposition of soil after heavy rains in Hongkong in 1958

Soil Conservation

Soil erosion has made millions of acres of land unproductive. As the world's population increases year by year, so more and more food has to be produced if famine and disease are to be eliminated, and if all people are to get an adequate and balanced diet. The governments of most countries have long since realised that soil erosion is one of Man's greatest enemies, and measures are now being taken to reduce erosion to a minimum and to reclaim land which has already been eroded. International organisations like the Food and Agriculture Organization (F.A.O.) have for many years been carrying out a programme of soil conservation. This has involved the introduction of sound methods of farming which not only prevent erosion but which also keep the soil in a healthy state.

Types of Soil Conservation

1. *Contour Ploughing*
   The furrows in which the crops are planted follow the contours. If they go up and down the slopes they promote gullying. The top photograph is an aerial view of contour ploughing in Texas.
2. *Terracing*
   The slope is cut into a series of wide steps on which the crops are grown. This is very common in Asian countries in regions of rice cultivation. The rice terraces are flooded during the growing season, the water passing from one terrace to the next one below it. The flooding of the terraces is a good indication of the ability of the terraces to prevent soil erosion.

Contour Ploughing in Texas

Terrace Cultivation in N. China. The low embankments around the fields protect the soil from erosion by preventing the water from rushing down the slopes

3 *Planting of Shelter Belts*
Belts of trees are often planted across a flat region which is liable to suffer from wind erosion. The trees break the force of the wind and thus protect the strips of land between the belts from being eroded.

Shelter Belts in the Dry Steppe in U.S.S.R. The belts consist of trees.

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THE AUTHOR: R. B. Bunnett, who is now Director of the publishing house Longmans of Malaysia, took his B.Sc. in Geography and Education at the University of London. He has taught in the United Kingdom, Ceylon, and Singapore, and was an education officer for Britain's Overseas Civil Service. He has published several texts for secondary-school students on map reading and geography.

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