

PRINCIPLES OF GEOGRAPHY

Part I

A Textbook for Class XI

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राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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GANDHIJI'S TALISMAN

"I will give you a talisman. Whenever you are in doubt or when the self becomes too much with you, apply the following test :

Recall the face of the poorest and the weakest man whom you may have seen and ask yourself if the step you contemplate is going to be of any use to him. Will he gain anything by it ? Will it restore him to a control over his own life and destiny ? In other words, will it lead to Swaraj for the hungry and spiritually starving millions ?

Then you will find your doubts and your self melting away."

M.K. Gandhi

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THE CONSTITUTION OF INDIA

PREAMBLE

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a
[SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC] and to secure to all its citizens:

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity;

and to promote among them all

FRATERNITY assuring the dignity of the individual and the ² [unity and integrity of
the Nation];

IN OUR CONSTITUENT ASSEMBLY this twenty-sixth day of November, 1949, do
HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.

1. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2, for "Sovereign Democratic Republic"
(w.e.f. 3.1.1977)
2. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2, for "Unity of the Nation"
(w.e.f. 3.1.1977)

Part IV A Fundamental Duties

ARTICLE 51A

Fundamental Duties -- It shall be the duty of every citizen of India--

- (a) to abide by the Constitution and respect its ideals and institutions, the National Flag and
the National Anthem;
- (b) to cherish and follow the noble ideals which inspired our national struggle for freedom;
- (c) to uphold and protect the sovereignty, unity and integrity of India;
- (d) to defend the country and render national service when called upon to do so;
- (e) to promote harmony and the spirit of common brotherhood amongst all the people of
India transcending religious, linguistic and regional or sectional diversities; to renounce
practices derogatory to the dignity of women;
- (f) to value and preserve the rich heritage of our composite culture;
- (g) to protect and improve the natural environment including forests, lakes, rivers, wild life
and to have compassion for living creatures;
- (h) to develop the scientific temper, humanism and the spirit of inquiry and reform;
- (i) to safeguard public property and to abjure violence;
- (j) to strive towards excellence in all spheres of individual and collective activity so that the
nation constantly rises to higher levels of endeavour and achievement.

UNIT I

Introduction

CHAPTER I

Geography as a Discipline

YOU were introduced to geography at a very early age. You explored the environment starting from your doorstep to the entire world gradually. In the process you were exposed to a richly varied body of facts about natural and cultural phenomena and about places and people on the earth's surface. You learnt to organise and analyse the diverse factual knowledge to construe meaningful patterns of man-environment inter-relationships. In brief, geography has made you aware of the world around you and has developed a broader outlook. Along with history, civics and other social sciences, it has enabled you to be a better citizen.

But have you ever wondered about the nature and scope of geography? Why is it important? What methods and techniques are used by geographers? It is necessary to pause and ponder over these questions as they will help us to clarify our views about the subject.

What is Geography?

The word geography is a combination of two Greek words which meant 'The earth' and 'to write or describe'. A literal definition of geography, therefore, could be 'to write about the earth including all that appears upon it'. Though it gives a broad idea of geography, it does not provide a complete picture of the nature and scope of geography, which has expanded and got sharpened over the years.

Geography as a body of knowledge has great

antiquity. Initially all information concerning the earth were catalogued under geography. Most of these information came from the scholars of other disciplines. Hippocrates discussed the effects of environment on man. Aristotle in his *Politics* showed the importance of geographical factor in the foundation of a State.

The foundations of geography as a discipline was laid down by the works of the Indian, the Greek and the Arab scholars, who tried to understand the universe around us and the place of our planet within it.

During the eighteenth century, discovery of new lands and ocean routes provided fascinating geographical accounts of voyaged new places and people. These accounts were also given a political value in Europe due to European colonial conquests. By the beginning of the nineteenth century, a systematic study of these geographical accounts had started. The German geographers A.V. Humboldt and Karl Ritter were the pioneers. The subject gained popularity in schools because it helped in knowing distant lands to the prospective traders, administrators and settlers. One with besides description, geography also provided explanation for the varied responses of human beings to their natural environment. The geography at the beginning of the twentieth century had emerged as a study of man-environment relationships. But throughout its existence two main schools of thought

concerning the relationship between man and environment. One of the schools popularly labelled 'Possibilism', viewed human beings as capable of modifying the environment and making use of the numerous possibilities offered by nature according to their own choice. This school followed the ideas of Vidal de la Blache and L. Febvre. The 'Determinist' school, on the other hand, holds that the environmental controls determine the activities of man very closely and thus offer little free choices to man. F. Ratzel and E. Huntington belonged to this school.

H.J. Mackinder strongly advocated for synthesising physical and human facts into a regional picture. He also maintained that political (human) geography could not exist independently of physical geography. Both schools of thought would probably agree with Mackinder's notion that geography is characterised by its outlook rather than by a clearly defined field of factual information.

The most recent development in geography is concerned more with technique than with a general approach to the subject. There has been an increase in the use of statistical analysis involving the use of mathematical processes. These techniques have gained wide acceptance in geography because (i) it provides scientific and objective information about the relationships between physical and human factors; and (ii) numerous and complex factors can be more simply summarised. S.W. Woolridge, R.J. Chorley and P. Haggett were the pioneers who used quantitative methods successfully in physical and human geography, respectively.

As we have seen earlier, geography has developed very fast in the past two hundred years, whereas its knowledge was available since ancient times. In fact, geography as an independent discipline and a subject for teaching at higher levels was recognised only during the nineteenth century. Today geography

is considered as a science having its own point of view which studies *areas* and all features—natural and cultural within them.

Aims and Objectives of Geography

The aims and objectives of geography, thus, become clear. The principal aim of geography is to understand an area as a part of the earth's surface, in its totality as an animated aspect of nature's creation. In studying this totality, it often becomes necessary to study with greater precision one particular aspect that contributes to the totality. Thus we may study, for example, the Rajasthan desert—its natural setting and the human response, by considering all the important natural and man-made aspects which distinguish this region from its neighbour. We may also study, more specifically, features like the micro-climatic variations in the Rajasthan desert or the behaviour of ground water in it. The first approach is often termed regional geography, and the second systematic geography. It is possible, and indeed desirable, to apply both these approaches.

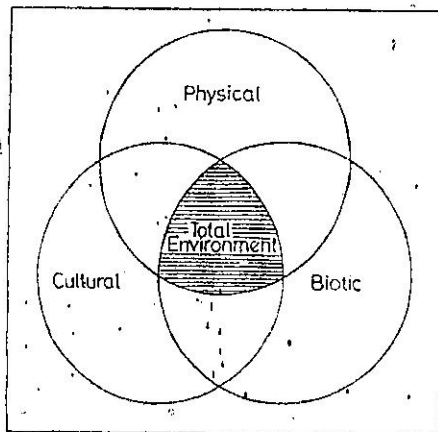


FIG. 1.1 Total Environment

Methods and Techniques

For realising its aims and objectives,

geography has its own methods and techniques, which have progressively gained precision and some sophistication. We shall acquaint ourselves only with the major aspects. In the first place, geography heavily depends, as do other sciences, on scientific methods and logic. This implies an orderly way of gathering the facts that are relevant, classifying them on the basis of similarities and an effort based on clear reasoning to draw some meaningful inferences. By techniques we mean the ways in which the facts are sifted, processed and interpreted. The use of right techniques for a given geographical problem or a situation depends upon the skill of the geographer. Geographers use a variety of materials in their analysis. For example, second hand information such as published maps and statistical information or data, as well as first hand information which they collect through field studies provide the basic material. They transform and interpret the data by using (a) cartographic and (b) quantitative methods/techniques.

We should, however, remember that while doing this task the geographer's attention is restricted to the area under study and the changes taking place within that area. Throughout the study two important questions are before him/her: (a) what are the patterns and processes involved in the changes taking place in the area under study, and (b) how does man's effort express itself in the terrain, and what could be the meaning of the pattern, process and human response? Do they show some commonness? Do they, in other words, conform to some tendencies or laws?

In developing this reasoning the geographer uses, what the students of logic term, deductive and inductive methods. We shall not go into the details. Deductive implies conclusions arising from a stated premise. Inductive means gathering a set of facts and trying to identify the commonness in the observed patterns and

associations. In both cases, we try to set some meaningful inferences and more important we try to test whether our inferences are correct or otherwise. This testing is called empirical testing. As we proceed to learn more about geography, we will come across Christaller's pattern of settlement hierarchy or W.M. Davis's 'cycle of erosion'. Air photographs, satellite imageries and computers have considerably strengthened the tools of the geographer. Thus, the geographers' methodology and techniques have become more precise and capable of meaningful inferences. These practical aspects of gaining direct experience of geographical phenomena can be acquired with the help of the companion volume, 'Fieldwork and Laboratory Techniques in Geography and other similar books.

Relation to Other Disciplines

Though geography draws a great deal of its content from other sciences—both natural and social, it has its own point of view which distinguishes it from those sciences. Besides getting enriched by such associations, geography has also contributed to allied sciences. Hence there are several interdisciplinary areas in Geography. For example, sub-fields of geography like geomorphology, economic geography and bio-geography are closely linked to geology, economics and life sciences (botany and zoology) respectively.

Specialisation in Geography—Main Branches

Geography has two distinct sub-fields—physical and human. On the basis of their origin, geographical elements of an area can be classified into two broad groups: the natural or physical and the human, that is, man-made or influenced by man. The natural features are the creations of Nature, independent of man, like mountains, rivers, natural vegetation, animal life and the like. The human or man-made features are those

created by human groups in their efforts to live in their habitat with ease and security. Agricultural fields, villages, factories and roads, are some examples. As they express the culture of human groups, they are usually, called cultural features. But, in addition, there are some aspects which are not visible expressions, and yet materially influence human action in environment. These largely belong to the realm of thought. Our thinking, perception, and reasoning, our capacity to absorb knowledge, our view of life, as expressed often through our religion and education, all these are non-material elements, which need to be taken into account. Some of them do express themselves in visible forms like a school building or a religious place, but most of them make a powerful impact on human behaviour in space. The choice of a place to

locate an industry and the journey to work (from home to the place of work) in a city, may be cited as examples to show the nature of this impact.

We need hardly warn ourselves that physical and human are two convenient divisions made by us for understanding Nature better. Nature represents a unity in its existence.

Sub-fields of Physical Geography

Geomorphology, the science which studies landforms is a rapidly emerging science to which important contributions have been made by geology, geography and climatology. In regional geography, the understanding of the terrain and its main and detailed features is indispensable, and as such geomorphology provides the base for geography.

Climatology, though a science almost

independent by itself, is also a necessary part of physical geography. It helps us to understand the processes responsible for the making of the weather and climate. *Hydrology*, an emerging science, helps us to grasp the processes whereby water plays its role in nature through oceans, rivers, glaciers, etc. and in sustaining its life forms. *Soil geography* which is a part of pedology, deals with the kinds of soils, their evolution, regional distribution and their role in land use.

Sub-fields of Human Geography

The main sub-fields of human geography are: *Cultural geography* which deals with the cultural aspects of different human groups. Cultural aspects include man's habitat, clothing, food, shelter, skills, tools, language, religions, social organisation and his outlook. As civilisation advances, all these and other aspects present a variegated form both in function and spatial distribution. Some geographers prefer to call this sub-field *Social geography*. *Economic geography*, a rapidly developing sub-field, concerns itself with man's activities in improving his material well-being through economic production, exchange distribution and consumption of useful goods and services, that human groups and their members need. How these activities develop in a region, through man's use of the region's natural resources and how they are either locally consumed or sent out of the region to some other region in exchange, are the main concerns in economic geography.

absolute numbers, birth rates and death rates, age-sex composition, levels of nutrition and literacy, may be said to be the principal aspects of this study with reference to their spatial distribution of the various forms in which human groups settle in a region. The principal forms are house types and settlements, rural and urban, ranging from a hamlet to a modern metropolitan city. *Historical geography* seeks to build up the geographical picture of a region or area, as it has evolved during the years in the past. It gives us important clues in understanding the region as it is at present. *Political geography* aims at analysing political and administrative decisions or choices of organised human groups in their spatial setting. Relations between independent states, frontiers, boundaries, federalism, local government and regional planning are some of its principal concerns.

So intense has been the recent research in geography that each of its many sub-fields has led to further specialisations. We may mention only a few to understand this development. In geography, for example, *glacial*, *coastal*, *climatic* and *anthropogenetic* (i.e., landforms influenced by man's action) geomorphologies are making a significant contribution. Micro-climatology is another example, on the physical side of geography. On the human side, there has been a powerful emergence of specialisations in economic geography, in the form of *agricultural*, *industrial*, and *transport* geographies. Medical geography is a specialisation which has emerged from biological aspects of interaction of man in his environment.

Regional geography: We now come to an important aspect of geography that is not a branch or sub-field, but rather a counterpart of these aspects. It is a study of a region at different scales—continents, countries, regions, local areas, etc.—in all its geographical aspects. Identifying the main geographical

Population geography mainly deals with those biological and cultural characteristics of human groups which strengthen or weaken the groups in their effort to develop the resources of their region and their capacity to live in comfort in their habitat. Human groups in their

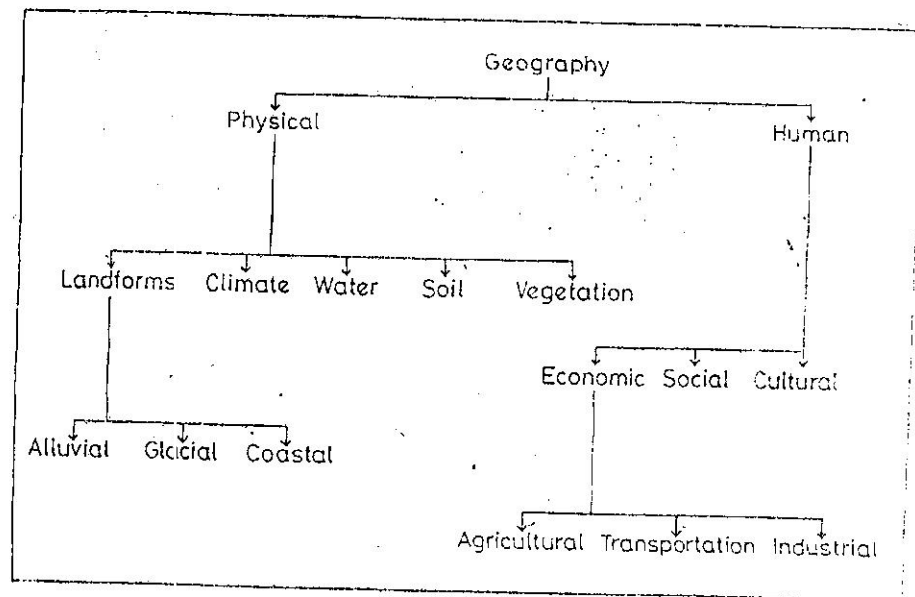


FIG. 1.2 Geography as a discipline

characteristics of a region, the interplay between man and nature and its impact, on man and nature's resources, delimitation of geographical regions, status and relations between regions of different sizes and regional planning, are some of the principal concerns of regional geography. In fact, regional geography is a summation of the findings of other sub-fields and specialisations in geography that are relevant to the area under study. We shall make this clear by examining the relation of regional geography to other branches of geography which are usually termed together as systematic geography.

Systematic Geography and Regional Geography

In identifying the branches and sub-fields of geography and what regional geography implies, we can see that there are two ways of studying a geographical phenomenon. One way is to select one geographical factor such as climate and study its world-wide distribution, recognise the climatic regions over the globe and go into the detailed regional climatic types and sub-types. Such a study of climate can be done at any scale of the area: India and its climatic regions; the climatic regions of Rajasthan with its north-western region of arid climate and the south-eastern semi-arid climate of the Aravallies, the highlands and surrounding sandy plain of the Luni Basin, both of which are a part of south-western Rajasthan. This study of a specific geographical factor is known as the systematic approach in geography.

Regional Geography, on the other hand, considers the area as a whole first and aims at identifying those geographical factors or components which in their union create the distinct character of the region. In the process, it examines the man-environment relationship with the constant change that is taking place within it. This is done by integrating the findings available as regards individual geographical phenomenon. It will be readily seen

that systematic geography contributes its finding and regional geography presents an integrated picture of the region as a whole. It also compares the region under study and its relationship with neighbouring ones. This aspect is called 'space-relationship'. Further, the study of regional geography implies demarcation of regions and sub-regions within the study area. The process of identifying various regions is often called *regionalisation*. This aspect also includes the study of the status, that is, the place of various regions, sub-regions, even smaller regions, and the linkages between them in their interactions. It is usual to call this procedure a classification of regions and identifying the *regional hierarchy*.

We may briefly illustrate these concepts and procedures by continuing our example of Rajasthan. Broadly, the most prominent geographical factors operating in the area delimited by the boundary of the State are its rocky and sandy terrain, its soils, more so its arid climate, the expanses of desert interspersed by scrubby grasslands in low-lying basins and occasional strips of agricultural land supported by local wells. The density of the population is low and has settled in small widely distributed villages and hamlets, many of which are the homes of cattle-rearing nomadic communities. Communications are few and far between and most of them connect the ancient towns of Rajasthan like Jaipur and Jodhpur. It may be seen that human life and the pattern of living are highly influenced by its arid and semi-arid climate. Altogether, the picture of man-environment relations is one of man's strenuous effort to improve his economic status and his living, in an environment which is harsh. We build this regional picture of ours with the help of maps, statistical data and other sources. We aim at integration of our material so gathered to understand Rajasthan as a geographical region.

We further try to identify sub-regions and their smaller regions, on the basis of relevant factors. Thus, Rajasthan may be divided into the arid north-western region and the partly forested, hilly region of the south-east. The south-eastern region can be further classified into (a) the Nemada hills, (b) the Udaipur hill complex, (c) the Luni border lands, and (d) the Aravalli hill complex, on the basis of terrain and land use characteristics. Each of these smaller regions can be further broken down into still smaller geographical regions.

Here, we should note that the technique of identifying and demarcating regions, or regionalisation, has become more precise and objective over the years. Geographers used to classify regions on the basis of their intimate

understanding of the region and on the basis of factors which they regarded as most relevant at each stage in classification. Nowadays, with the use of refined cartographical and statistical techniques, it is possible to demarcate regions more objectively and weigh their place in the regional hierarchy, with a greater precision. Such exercises are useful not only to gain a good insight into the regional geography of the land, but also for regional planning and development. Now we have some good studies of our country as a whole and for some of its regions in greater detail.

We have thus seen that geography as a field of study has an useful contribution to make in our study of the earth and its various regions.

EXERCISES

Review Questions

- Answer the following questions:
 - Name the scholar of ancient times who talked about impact of environment on man?
 - Why did geography gain popularity in schools during the eighteenth century?
 - Name the geographer who advocated for the synthesis of physical and human geography.
 - What is the most recent development in geography?
- Write short notes on the following:
 - 'Deterministic' school of thought.
 - Relation of geography with other disciplines.
- Discuss the methods and techniques in geographical studies.
- What do we mean by regionalisation? Explain this method with the help of an example.

Finding Out

- Collect information regarding some eminent geographers of our own country and their contributions.

Further Readings

Freeman, T.W. *A Hundred Years of Geography* Duckworth, 1961.
 Woolridge, S.W. and W.G. East. *The Spirit and Purpose of Geography*, Hutchinson's University Library, 1951.

CHAPTER 2

The Earth—Its Origin and Evolution

The earth—our homeland is only one of the members of the solar system. It is, however, a unique planet because it contains life. Do you ever wonder how did the earth originate and evolve to become our homeland? Let us find answers to these questions in the following pages.

The Origin

Though it is not exactly known how the earth originated, one of the most favoured theory suggests that it is an outcome of a star formation.

About 4,600 million years ago, a giant cloud of gas and dust in space, having a swirling motion, gradually contracted under its own gravity. As it contracted, it assumed a flattened disc-like shape. The swirling is measured by a physical quantity called angular momentum. It depends on the speed of rotation and the size of an object. As the gas cloud or nebula shrank in size, it spun faster to conserve its angular momentum. The rapid rotation prevented it from total collapse into one object and a large number of smaller units were formed. The core of the nebula rotating fairly slowly eventually became the new star—the sun. The centre of this star was hot enough for thermonuclear reaction to set in. The smaller units retaining most of the angular momentum of the original cloud formed planets. Each unit contracted further and in this process began to get hotter in the centre.

Gradually the heavier dust particles settled towards the centre of the rotating disc leaving the gases farther out. Thus today the inner planets of the solar system are rocky and heavier while giant outer planets are lighter.

The Earth's Evolution

The earth has reached to its present form through several phases. From a ball of swirling dust and clouds, it passed through a molten stage. Light substances floated up from deep inside to lie upon its fiery surface. There, they cooled and hardened. So the earth gradually gained the skin of solid rock that makes up most of the earth's crust. As the earth's interior continued to cool, it contracted and the outer crust wrinkled forming ridges and basins. Meanwhile, still lighter substances floated up above the crust and formed an atmosphere of gases.

With the cooling of the hot gaseous substances in the atmosphere, massive cloud formation took place. It brought heavy downpour for thousands of years. As a result, the great basins on the earth's crust were filled with water. Thus oceans were formed.

For perhaps one half of the long span of earth's history, the planet earth remained barren and lifeless. Then life appeared miraculously in the oceans. It is difficult to say what exactly formed life. All that can be said is that through some agency certain giant molecules acquired the ability to duplicate

themselves. From such shadowy beginning emerged a wonderful world of living things—plants and animals.

Emergence of *Homo Sapiens*, the species that include all living races of human being about 500,000 years ago, is comparatively a recent phenomenon in the earth's history.

Major Surface Features of the Earth

The major surface features on the earth are continents and ocean basins. Of the whole surface of the earth, less than one-third is landmasses, the rest is covered with water. The maximum difference in elevation on the earth's surface is about 20 kilometres (between Mount Everest, 8,848 metres above sea level, and the Challenger Deep in Mariana Trench in the Pacific Ocean, 11,022 metres below sea level). Considering the size of the earth, the difference in surface relief is small indeed.

The continents and ocean basins are irregularly arranged on the earth. The northern hemisphere has more land than the southern hemisphere. But continents and oceans have not always remained the same as they are today. For several million years, large parts of continents were covered with thick masses of ice, as Greenland and Antarctica still are. This period on the earth is known as the *Ice age*. The ice-sheets melted only few thousand years ago, raising the sea-level to the present position. When the sea-level was lower, North America and Asia were connected by dry land where today exists the Bering Strait.

It is believed that continents have been drifting apart. This idea was first propagated by Alfred Wegener in 1924 and is known as the theory of continental drift. Accordingly, nearly 150 million years ago, there was a single continent on the earth known as *Pangaea*. This super-continent broke into several pieces, which began to drift apart. North and South

Americas pulled away from Africa and Eurasia, and drifted to the west. As a result, the western edge was wrinkled and the Rockies and the Andes were formed. In between the two continental blocks of the Americas on the one hand and the Africa and Eurasia on the other, the Atlantic Ocean basin appeared. Antarctica, Australia, Peninsular India and Madagascar were neatly nested together close to the southern tip of South Africa. These fragments also drifted away to the present positions, giving way to the Indian Ocean Basin in between.

Initially this theory was not acceptable to many scientists as the continental drift seemed impossible under the known laws of geophysics. However, in recent years the studies of the past magnetism of the earth as well as the new discoveries of the ocean floors have brought evolution in geology. It has been established by the theory of *Plate tectonics* that continents are moving as plates on a semi-liquid surface. Thus it now lends support to the theory of continental drift.

Now we have seen how the various realms of the earth—the lithosphere (the landmasses), the atmosphere (the air envelope), the hydrosphere (the waterbodies), and the biosphere (life forms) were created. These global realms together constitute our natural environment.

All these components of the environment are closely linked with each other through flow of energy and matter. Hence it is difficult to understand any physical phenomena in isolation. For example, water moves continuously between the atmosphere, the lithosphere, the hydrosphere and the biosphere. Considering the complex nature of the earth as a total system, we can proceed in a logical manner, piece by piece but we should never lose sight of the wholeness of the physical world.

EXERCISES

Review Questions

1. Answer the following questions:
 - (i) What is a nebula?
 - (ii) Why are the inner planets of the solar system heavier?
 - (iii) When was the earth formed?
 - (iv) What is a Pangaea?
2. Write short notes on:
 - (i) Ice age
 - (ii) Plate tectonics
3. Discuss the origin of the earth.
4. Briefly describe the continental drift.

Finding out

5. Collect information regarding continental drift, especially evidences in support of the theory

Further Readings

Strahler, A.H., A.N. Strahler, *Geography and Man's Environment*, New York: John Wiley & Sons, 1977.

James, P.E. *A Geography of Man*, London: Blaisdall Publishing Company, 1966.

UNIT II

The Lithosphere

CHAPTER 3

Interior of the Earth

THE detailed study of the interior of the earth is generally undertaken by geologists and specialists in Earth Sciences. But we need its elementary knowledge in geography because this understanding is essential to follow the nature of changes taking place on the earth's surface. The uplift of great mountains, the subsidence of parts of the crust, its expansion or contraction are related to internal forces operating below the earth's surface.

Evidences about the Earth's Interior

Exploring the earth beneath our feet is a more difficult task than mapping the moon. A scientist can look far into space but such is not possible in the case of the earth's interior. The deepest mine in the world in South Africa is about 4 km deep. In search for oil man has dug a hole only about 6 km deep. None of these places are very far down compared with the distance to the centre of our earth. A borehole to the centre of the earth would be over 6,000 km deep in ocean floor. Still without drilling, a number of things have helped explorers to know about the deep earth. Only upper part of the earth's crust just below its surface could be known more or less by direct observations. Lower part is beyond the reach of direct observations and our knowledge about it is based upon indirect scientific evidences. These indirect sources are temperature and pressure inside the earth, density of its

different shells, behaviour of earthquake waves and evidence from meteorites. Still uncertainties persist about the actual state of matter in the innermost zone around earth's core. As such scientists do not agree on a precisely uniform thickness and classification of the layers of the earth's interior.

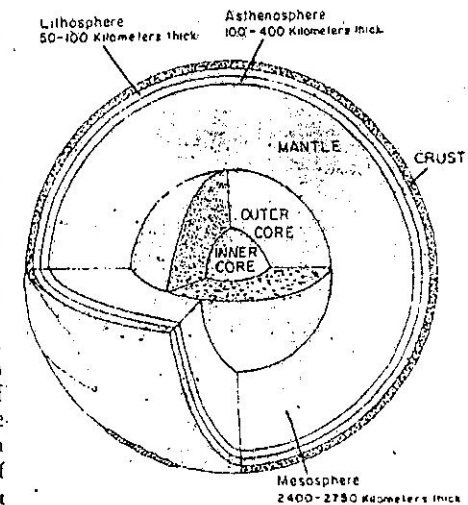


FIG. 3.1 A section through the earth showing its structure.

By using seismograph, a graphic recording of the earthquake waves or vibrations is made, and scientists are able to get some idea of the kind of rocks which are found below the earth's surface. There is a

change in the course and velocity of the waves on crossing the boundaries of different zones inside the earth. If the ground through which the waves travel is solid, they behave in one way. If it is liquid, the waves behave in a different way. Their velocities in both cases differ. There are three types of waves known as 'P' or longitudinal or primary waves, 'S' or transverse or secondary waves, and the long 'L' or surface waves which are recorded by a seismograph. The velocity of the first two types of waves increases with depth but only upto 2,900 kilometres. Afterwards, 'S' waves passing across the direction of their movement do not pass and the 'P' waves travelling in the direction of their movement generally pass at a reduced velocity. The long 'L' waves do not pass and do not go deeper in the earth. The 'S' waves cannot pass through a liquid and are transmitted only through a rigid or a solid body. The velocity of the 'P' waves passing through inner core again increases as compared to their passage through the outer core. This data briefly point out that

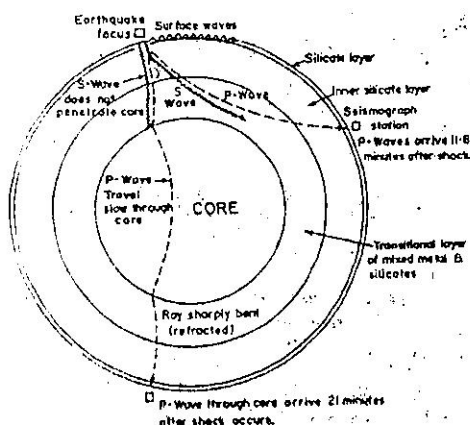


FIG. 3.2 Cross-section of the earth showing diagrammatically the paths of P, S and L

the inner core of the earth is of solid iron and the outer core has probably the properties of a liquid. It may be concluded that as a whole the earth behaves as solid even when parts of its interior are reported to be in a plastic or semi-liquid state. The rock samples from various depths, have also provided the evidence of the density of the materials. The meteorites belonging to our solar family are another source of our information for a better understanding of the earth's structure. Their outer layer is burnt during their fall to the earth. As the stony materials of meteorites are similar to those found on the earth's surface, these are scarcely recognised. But the composition of the meteorites consisting of heaviest materials confirms the similar composition of inner core of the earth.

Temperature and Pressure Inside the Earth

The evidence of volcanic eruptions and hot springs indicates that high temperatures prevail in the interior of the earth. A progressive rise in temperature with increasing depth is recorded in mines and deep wells all over the world, the average rate of increase being 1°C for every 32 metres of descent. Normally, at this rate of increase in temperature, the rocks at great depths should be in a liquid state. At one time, on the basis of this view, it was accepted that the thin solid crust of the earth was perhaps resting on a molten core. But the behaviour of earthquake waves as hinted above has led us to revise our views. The rate of increase in temperature is now considered to be variable and there is no uniform increase from the surface to the centre of the earth. The rate of increase in the overlying pressure makes the melting point higher but only to a certain degree. In upper 100 km, the increase is estimated at 12°C per km. It is 2°C per km in the next 300 km and 1°C per km below it. By this calculation the temperature is actually

$2,000^{\circ}\text{C}$ at the core of the earth. The heat or rise in temperature is the result of internal forces, automatic disintegration of radioactive substances, chemical reaction and other sources keeping the interior hot. It indicates the liquid or perhaps gaseous conditions prevailing at greater depths. But at the same time there is a tremendous increase in the pressure of overlying layers on earth's interior. Thus, even under extremely high temperature towards the central part of the earth, the liquid nature of its core has acquired the properties of a solid and is probably in a plastic state. The earth is rigid and behaves mostly as a solid down to a depth of 2,900 km because of such

pressure conditions. Wherever even a slight release of pressure occurs, the underlying matter escapes to the surface and becomes molten because of high temperatures prevailing there. While solid material melts inside the earth, the liquid also takes up the properties of a solid as alluded above.

Density and Composition of the Earth's Interior

The velocity and the path followed by earthquake waves, temperature and pressure conditions inside the earth tell us of varying physical properties, density and composition prevailing there. The structure of the earth's interior is therefore layered. The arrangement of layers is comparable to

Table

Name of the Layer	Chemical Composition	Average Thickness	Density	Physical Property
A. i. Crust or outer part of lithosphere immediately below the newer sedimentaries on surface.	SIAL (Sedimentary and the granitic rocks)	8 to 45 km (mainly under continents)		Solid
ii. Inner part of lithosphere or the substratum of greater strength.	Or outer silicate layer	45 to 100 km (partly under oceans)	2.75 to 2.90	Partly molten
B. i. Inner silicate layer.	SIMA (in part) (Basic rocks)	100 to 1700 km (mainly under oceans)	3.1 to 4.75	Some properties of a solid and some like those of plastic material close to melting point.
ii. Transitional zone of mixed metals and silicates.	Wholly SIMA (ultra-basic rocks)	1700 to 2900 km	4.75 to 5.00	
(B. i. and B. ii. together constitute the mantle)				
C. i. Outer metallic core.	NIFE or	2900 to 4980 km	5.1 to 13.00	Liquid or in a plastic state. Solid and rigid because of tremendous overlying pressure.
ii. Inner metallic core.	Barysphere (Heavy metallic rocks)	4980 to 6400 km		

onion with its shells, one inside another. The inside of earth has a shallow crust as thin as an egg shell which can be compared with the size of a ball. Below the surface capped by sedimentary material, upper layer of the crust is mainly composed of crystalline igneous and metamorphic rocks, acid in nature. The lower layer of the crust has basaltic and ultra-basic rocks. The layer of heavier or inner silicates is not found beneath oceans. The oceans are mostly underlaid by dark coloured basalt followed down by a thick greenish and tremendously hot layer. The continents are composed of lighter silicates termed as 'Sial' or Silica + Aluminium. The oceans have heavier silicates named as 'Sima' or Silica + Magnesium. The continents of lighter material are floating in a sea of heavier and denser material. The central core has the heaviest mineral materials of highest density. It is

composed of what is termed as 'Nife' or Nickel + Iron. A zone of mixed heavy metals and silicates separates the core from the other layers.

The Table on page 5 summarises the names, density and approximate thickness of different layers of earth's interior in order to know its structure.

Based upon variations in temperature and pressure, changes in density and velocity of earthquake waves along boundaries of different layers, their chemical composition and physical properties, layered nature of earth's structure is confirmed. Broadly, there are three layers—the crust, the mantle and the core. While the crust forms only 0.5 per cent of the volume of the earth, 16 per cent consists of the mantle and 83 per cent makes the core. Earth being a spherical body, it has its centre at 6,400 km viz., the mean radius of the earth.

EXERCISES

Review Questions

1. Answer the following questions :
 - (i) How is it that our knowledge is based on indirect observations about the structure of the earth's interior?
 - (ii) How the meteorites help us in telling the composition of the earth's interior?
 - (iii) What are the main evidences of the layered nature of the earth's structure?
 - (iv) What is the significance of the variations in temperature within the earth's crust?
2. Write short notes on :
 - (i) Sial, (ii) Sima, (iii) Nife, and (iv) Barysphere.
3. Discuss the structure of the earth, giving details about each of its layers or shells and arguments in support of your contention.
4. How do the waves of different types tell us about the change in the nature of different layers of the earth's interior?

5. Give a single term for each of the following :

- (i) Part of the earth's interior which behaves like a solid despite its high temperature.
- (ii) Chemical composition of the layer underlying continents.
- (iii) Part of the earth's interior consisting mixed metals and silicates.
- (iv) The waves which pass through the core of the earth.
- (v) Chemical composition of the layer underlying oceans.

Finding Out

6. Find out sufficient information about the use of studying earth's interior. Take clues from your textbook and other books available in your school library.

Cartographic Work

7. Draw a good cross-section of the earth's interior appending brief notes explaining the diagram. Label it suitably.

Further Readings

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CHAPTER 4

Materials of the Earth's Crust

THE outer part of the earth as we can see in quarries, cuttings along roads, mines or borings is the earth's crust. This most significant outer crust of the earth is part of the lithosphere. The word 'Lithosphere' means a sphere of rock, whether hard as granite or soft as clay, gravel or sandstone. Down to a depth of 16 km from the surface of land, 95 per cent of the earth materials found in the earth's crust consist of rocks.

Rocks and Minerals

Rocks are made up of individual substances, which are called minerals found mostly in a solid state. Each mineral usually contains two or more simple substances called elements of which the whole earth is made. Out of about 2,000 different minerals, only twelve are common all over the earth. These twelve minerals are called the rock-formers. Still the other uncommon minerals are also useful to industry and to modern way of life. The common minerals are formed of eight most abundant elements in nature. Out of these, silicates, carbonates and oxides make up a large group of them. As many as 87 per cent of the minerals in earth's crust are silicates. Quartz, for example, has two elements, silicon and oxygen, united together form a compound known as carbonate of lime. Each mineral is a naturally occurring non-living solid substance possessing certain physical properties and a definite chemical

composition. Minerals are thus chemical substances found in nature, may be either elements or compounds. There are metallic minerals like copper, lead and gold as well as non-metallic minerals like gypsum, quartz and mica.

The geologists are interested in rocks to know the geologic history of the earth, because it is in fact written in rocks. But for geographers, they are important as elements of natural environment and are valuable for their minerals and the soil they produce. The useful products like petroleum and the underground water are also found in rocks.

Classification of Rocks

On the basis of the mode of formation, rocks are usually classified into three major types. One such type may be distinguished from the other not only on the basis of its origin but also with reference to mineral contents and arrangements of mineral crystals.

1. Igneous Rocks

At one time, all parent rock material was liquid, hot and a sticky thing called magma. This rock-forming hot liquid generally moves towards the surface from 60-100 km depths when steam pushes it up through cracks. It hardens below or upon reaching the earth's surface. When it hardens, it forms igneous rock (*ignis* in Latin means fire). Igneous rocks are parents of all other rocks and are also known as primary rocks. They

have been forming since earth began and are still formed in regions of volcanic activity.

Extrusive igneous rock is the name given to magma erupting and solidifying after escape of gases as lava on reaching the surface of earth. This variety is also named as a volcanic rock. As lava cools down rapidly on coming out of the earth's hot interior, the mineral crystals of extrusive igneous rocks change their structure and are very small, making them look fine-grained. A virtual absence of grains as in obsidian gives them a glassy appearance. Basalt is a typical example of extrusive type, covering 500,000 sq km of Peninsular India in its north-western part. These are the Deccan Traps forming flat-topped hills at present. The basaltic material is used for building roads and yields a fertile black soil locally known as *regur*, on its weathering.

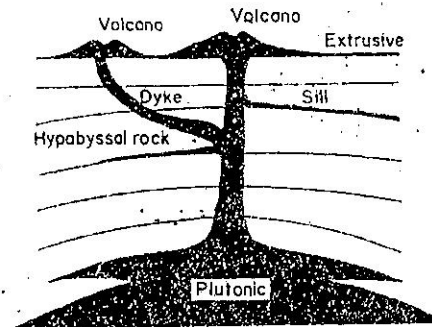


FIG. 4.1 Igneous rocks

The intrusive igneous rock is formed by solidification of magma at moderate depths beneath the earth's surface. The cooling is obviously slow because of the great heat at these depths and the crystals formed are large. The granite and the dolerite are the most common examples of such rocks. For this reason granite is coarse-grained unlike the fine-grained basalt. On the other hand,

when solidification of magma occurs at great depths below the earth's surface, the rate of cooling is much slower. As a result of this slow cooling, very large-sized crystals are formed in such rocks. These deep-seated intrusions are known as plutonic rocks. The word 'Plutonic' is derived from the word *Pluto*, the god of the underworld. A highly coarse-grained granite is a typical example of plutonic rock. The granite of various colours—grey, red, pink or white is found on the Deccan Plateau in south India, in Madhya Pradesh, Chota Nagpur, Rajasthan and in parts of the Himalaya. During its molten state within the earth it contained water, steam and various gases which escaped on solidification of the material. It is used largely as a building stone and many ancient monuments like temples are made of granite rocks.

All igneous rocks are of magmatic origin and each intrusive type has an extrusive equivalent. They are massive having no layers, hard, compact, free of fossils and dark as basalt or light-coloured as granite depending upon greater or lesser amount of silica present in them. Those with a high proportion of silicon are said to be acid and others with a high proportion of basic oxides are denser and darker in appearance. These are crystalline rocks because each has crystals formed as a result of the process of crystallisation for a longer or shorter period.

Since magma is the chief source of metal ores, many of them are associated with igneous rocks. The minerals of great economic value found in them are magnetic iron, nickel, copper, lead, zinc, chromite, manganese and rare ones like gold, diamonds and the platinum. These are of great value in metallurgical industry of modern days. Many of these metals are derived from crystallised minerals usually filling the fissures in the rocks. The water laden with mineral matter in solution,

passing through these fissures in the rock is responsible for the deposition of rich minerals. Mixed with plenty of quartz and calcite formed in this way are the ores of lead, zinc, tin, copper and other rare metals. Occasionally uncombined metals are found in native state as gold and copper. Igneous rocks abound in silicate minerals containing iron and magnesium. Some mica is also associated with them. The old rocks of the great Indian Peninsula are rich in these crystallised minerals or metals.

Igneous Rock Bodies

All structural mountains formed as a result of uplift have igneous rock bodies within them. These bodies of different shapes and sizes are formed of solidified magma and are named with reference to the surrounding rock, their own size, shape and position. The intrusive igneous rock bodies include batholiths, stocks, laccoliths, sills and dykes. These volcanic formations are formed much below the ground surface. We know about them on their exposure on the earth. As the loss of heat is much slower inside the earth, the crystals grow larger during a prolonged process of crystallisation. The extrusive igneous rock bodies form volcanic mountains or volcanic plateaus within areas of mountain building and on the floor of oceans. We would read about them in some details in other chapters.

Batholiths are the largest intrusive igneous rock bodies. They may be 50 to 80 km across and hundreds of kilometres in length. They are so thick that their bottoms are not visible. We see them on the surface only when large amount of surface rock has been carried away. Their upper surface is irregular and dome shaped. The batholiths are great granite masses forming the cores of world's mountain systems. The batholiths covering smaller areas are called *stocks*

having somewhat rounded form and same general characteristics.

The *Laccoliths* are other huge masses of igneous rocks that have been formed between horizontal or slightly tilted layers of sedimentary rock nearer the earth's surface. The dome shaped masses of magma due to rapid movement upwards appear in the form of a mushroom or a loaf of bread. It may be regarded a miscarried volcano when the magma failed to break through the surface. It is possible that at some depth under the active volcano, there is a laccolith in the form of a reservoir of magma producing the eruption. In other words, a laccolith can be cited as an intrusive equivalent of an extrusive nature of a volcanic formation.

The *Dykes* are near vertical formations, from a few metres to kilometres in length and from a few centimetres to hundreds of metres in thickness. They come into existence when liquid material passes through cracks in the country rocks and gets hardened into a rock. They are not easily eroded and stand like great walls after the country rock is eroded.

Sometimes, magma trying to reach the surface squeezes between two rock layers and solidifies into a thin sheet in horizontal position parallel to the layers of already existing rocks. Such an intrusion is termed as a *Sill*.

2. Sedimentary Rocks

Although three-fourths of the earth's surface is covered with sedimentary rocks, they make up only about 5 per cent of the volume of the earth's crust. In other words, sedimentary rocks are not as important as igneous rocks in depth of the earth, they are widespread in their extent.

Any rock on the earth's surface is exposed to weather changes and to the agents of erosion. It thus gets broken into fragments,

one or the other type are carried by running water, wind or ice. These are left buried layer by layer at favourable sites, mostly settling down along silent water of a stream, a lake or sheltered parts of sea and its beaches. The sediments get sorted by the transporting agents like running water, winds, waves; the larger and heavier particles being deposited first after moving for a relatively short distance. The smaller and finer particles are carried far away. But most of the material transported by moving ice are not sorted out and are all dropped together when the ice melts. As sedimentation is favoured by water, most of the sedimentary rocks have been formed under water. The loess is one example of fine sand carried by wind and deposited as wind-borne sedimentary rock as in north-western China and Indian sub-continent. An unsorted mixture of clay and boulders known as boulder clay or 'till' is an example of ice-deposited sedimentary rock as in plains of northern Europe.

Very often, loose and unconsolidated rock materials such as sand and clay, in course of time, get converted into hard and compact rocks such as sandstone and shale, respectively. They get hardened by compaction, i.e., by the pressure of some overlying material. While sand and clay generally turns into compact rocks by pressure, conglomerate and breccia are the examples of sedimentary rocks formed because of the process of cementation. Some sort of cementing stuff like calcite or silica is carried by water in solution. It collects around grains and pebbles and binds them together into a solid mass. The conglomerate is a collection of round pebbles taken from a sea shore or a riverbed mixed and bound together by some cementing stuff. The pebbles in the case of breccia are angular fragments indicating the work of an agent other than running water or moving ice. Such a process of formation

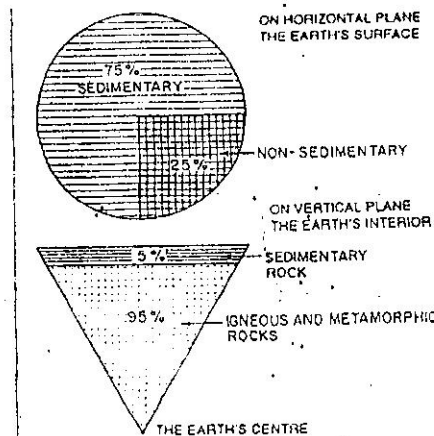


FIG. 4.2 Distribution of rocks on horizontal and vertical planes of the earth

further reduced into small particles called sediments. These are derived from igneous, metamorphic or older sedimentary rocks. For this reason these are known as sedimentary or fragmental rocks.

Some sediments are of sand, some of clay and others are of different bits of rocks making pebbles or gravel. All sediments of

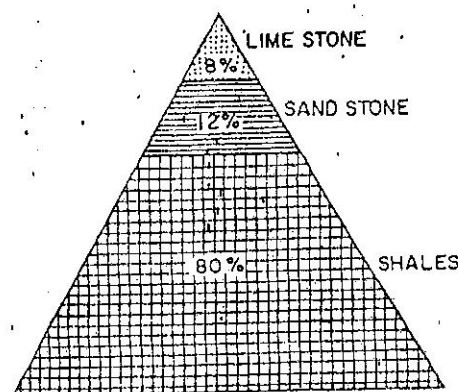


FIG. 4.3 Composition of sedimentary rocks by types

places all these rocks under the category of mechanically formed sedimentary rocks.

The organic matter derived from plant or animal remains is also the raw material for the formation of sedimentary rocks in course of time. Two well-known examples of sedimentary rocks of organic origin are coal and the limestone. Many a time, plants, their roots, leaves, twigs and even tree trunks are buried in swamps. In course of time, these materials are partially decayed, losing most of their elements except carbon. The accumulated material turns into coals of different grades depending upon the proportion of carbon and the degree of overlying pressure. The peat and lignite (brown coal) is the first stage of coal having below 45 per cent carbon and bituminous variety is the next stage with 60-70 per cent carbon. Likewise, the limestone is composed of shells and skeletons of dead marine animals once living in moderately deep, warm and clear waters of a sea or a lake. The lime shells of such organisms are cemented into limestone sedimentary rock of organic origin. The tiny organisms like corals and algae derive calcium carbonate from the sea water. Such are the reefs built from the skeletons of dead corals once living in tropical seas.

Still another category is the result of direct precipitation of minerals from their solutions in water. The rock salt, gypsum, and nitre like saltpetre are examples of such chemically formed sedimentary rocks as a result of evaporation of substances held in solution by water. It takes place when rivers in hot climates pour such salts into inland lakes and sea in such a large quantity that the surplus is removed by evaporation.

All sedimentary rocks are layered, lying in horizontal beds. If their position is disturbed after the deposition, the beds are slightly inclined. As sediments are usually deposited in distinct layers or strata, these rocks are

termed as stratified rocks. Most of them have ripple marks left by water. They have fossils embedded into their layers. They are in the form of prints of leaves, insects or soft-bovine animals and pieces of bones, shells or some hard parts of old living beings. The large variety of sedimentary rocks are distinguished by the origin of sediments, mode and place of deposition and nature of cementing material, although they retain their common characteristics.

The minerals of economic value are less in sedimentary rocks. But these are the source of haematite iron ore, phosphates, a number of building stones, coal and materials for making cement. Petroleum formed by the decay of tiny marine organisms also occurs in the muds of sedimentary rocks. It forms oil pools only in some suitable structures. One of such structures, is the existence of a pervious stratum like sandstone between two strata of impervious rocks like shale. Its further movement is stopped by the impermeable rock and pressure helps it to rise in the porous rock. If the rocks are bent upwards as in an anticlinal fold, oil tends to rise to the top, being lighter than water. The decomposition of surface rocks under tropical conditions give us the secondary ores of bauxite, manganese, and deposits like tin derived from other rocks but found in gravels and sands carried by water. Sedimentary rocks also yield some of the rich soils.

In the Indian sub-continent, the alluvial deposits in the Indo-Gangetic plain is of sedimentary accumulation. Clay and loam of different kinds occur in this plain and in the east coastal plains of our country. Sandstone is found in large areas of Madhya Pradesh, eastern Rajasthan, in parts of Himalaya, Andhra Pradesh, Bihar and Orissa. The Red Forts of Delhi and Agra are made of red variety of sandstone. The great Vindhyan highland in central India consists

of sandstones, shales and limestones. The significant coal, as a source of power and as an industrial fuel occurs in the river basins of the Damodar, Mahanadi and Godavari in Gondwana sedimentary deposits. Assam and Gujarat are the chief petroleum producing states in India. But potential areas of new production are under exploration in sub-Himalayan zone, and river deltas of the Ganga and Kaveri. The suitable structure in the oceanic sedimentary rocks to the west of Bombay have started yielding petroleum. The prospects of new oil deposits exist in Rann of Kachchh, the Gulf of Cambay and the continental shelf off the Andhra coast.

Although derived from pre-existing rocks, it is interesting to note that some sedimentary rocks are older than either igneous or the metamorphic rocks as found in Greenland in 1973.

3. Metamorphic Rocks

Change is the law of nature. All rocks undergo changes. When the original character of the rocks—their colour, hardness, texture and mineral composition is partly or wholly changed, it gives rise to metamorphic rocks, under favourable conditions of heat and pressure. In Greek language the word *metamorphic* means 'change of form'.

These rocks are formed under conditions similar to those producing igneous rocks. The change takes place while the rock is in a solid or a plastic state mostly at depths of about 12-16 km below the surface. The process of metamorphism takes place at depths under the pressure of overlying rocks or as a result of contact with a hot igneous material. The formation of metamorphic rocks under the stress of pressure is known as 'dynamic metamorphism'. In this case, granite is converted into gneiss; clay and shale are transformed into schist at great

depths of the earth's crust. The gneiss and schist rocks have a well-marked banded structure in which the constituent minerals are arranged in nearly parallel layers. The bands in the case of a schist are thinner than those in the gneiss, and consist of the same aggregate of minerals. In India, both are commonly found over large parts of South India and in some parts of Assam, West Bengal, Bihar, Orissa, Madhya Pradesh and Rajasthan. They are also found in the Himalayas. Gneiss is largely used as a building stone and statues in the regions of its occurrence.

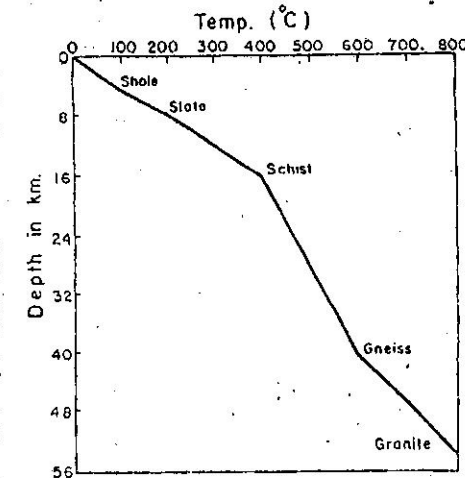


FIG. 4.4 Major rock types by depth

The change of form or re-crystallisation of minerals of sedimentary and igneous rocks under the influence of high temperatures prevailing within the earth's crust is known as the process of thermal or contact metamorphism. In areas of mountain-building or of vulcanism, molten matter may be injected into the existing rocks even close to the surface. Such a contact with heat

over a limited area of about 2 km from the intrusion brings about a change in rocks under temperatures ranging from 50°C to 800°C. Some such reason is responsible for the peak of Mt. Everest consisting of metamorphosed limestone. As a result of this type of metamorphism, sandstone changes into quartzite; clay and shale are transformed into slate. The coal turns into anthracite and graphite with over 90 per cent carbon. Marble becomes a metamorphic rock equivalent of sedimentary limestone. Slate may further change into phyllite under temperatures ranging from 150°C to 200°C. When all these forces of heat by intrusion or deep burial and earth movements act together over large areas, the widespread change of rocks is the result of regional metamorphism. The quartzite rock is one of the most resistant to weathering, forming mountains and ridges. It is used in glass-making.

In India, it is found in Rajasthan, Bihar, Madhya Pradesh, Tamilnadu and in the vicinity of Delhi. Marble is prized as a building stone. The majestic Taj bears witness to the grandeur of this rock. In India it occurs near Alwar, Ajmer, Jaipur and Jodhpur—all in Rajasthan and in the neighbourhood of Jabalpur along Narmada river in Madhya Pradesh. Slate is used for roofing and paving and for writing by school children. In India, it is found in Rewari (Haryana), Kangra (Himachal Pradesh) and in parts of Bihar. Graphite is used for manufacturing pencils and crucibles. It is found in Orissa and Andhra Pradesh.

The metamorphic rocks are recognized by their great hardness, closely banded structures and interlocking of crystals. During the process of change, not only new and precious minerals like gems, rubies and sapphires are born but crystals are enlarged and re-arranged and the addition of new

elements from the magma changes the rock composition.

Rock Cycle

All rock materials originating from beneath the earth's surface form igneous rocks. As soon as igneous rock is exposed to weather on the surface of earth, it is eroded by various agents. The material changes into sedimentary rocks at some place and at some point of time. Either of the two rocks are likely to change into metamorphic rocks in course of time. A change into sedimentary rock takes place at the earth's surface and conversion into a metamorphic rock takes place within the crust of earth. The sedimentary rocks may again be buried so deep that they melt forming igneous rocks. The change of one rock into another type under different conditions is known as rock cycle. The matter of earth's crust is not lost and the process changing one form to another becomes cyclic.

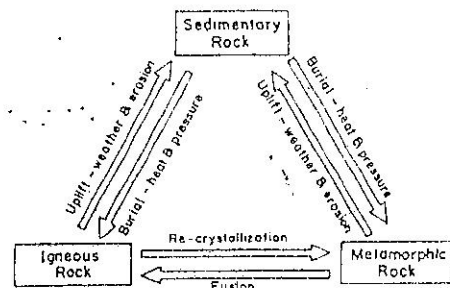


FIG. 4.5 Rock cycle

The sources of energy powering this cycle are two. First one is the heat deep within the earth capable of melting the previously existing rock. It may also bring about changes in a rock while it remains solid. The second is the solar energy responsible for breaking and decomposing the rocks on

earth's surface for converting them into sedimentary rocks. Deep burial and strong compression during a mountain-building activity may also change the sedimentary into metamorphic or igneous rocks. The metamorphic rock can also furnish

sediments to produce a sedimentary rock. All known materials in the form of minerals and rocks are defined as mineral matter. Throughout hundreds and millions of years, the rock cycle has been re-cycling the mineral matter of the earth's crust.

EXERCISES

Review Questions

- Answer the following questions :
 - Distinguish between a rock and a mineral.
 - Define a mineral clearly.
 - Why are the igneous rocks called primary rocks?
 - Distinguish between the formation of limestone and coal.
 - Minerals found in both metamorphic and igneous rocks are the same. Explain why?
 - How can we distinguish an intrusive igneous rock from an extrusive volcanic rock?
 - Why fossils are preserved in sedimentary and not in igneous rocks?
- Write short notes on :
 - Intrusive rocks.
 - Factors controlling the properties of sedimentary rocks.
 - Batholiths.
 - Metamorphism.
 - Heat and pressure relationship in the process of metamorphism.
 - Breccia and the conglomerate.
- Under what conditions are mineral oil deposits likely to be found in the earth's crust? Illustrate your answer with a diagram.
- Discuss the classification of various types of rocks, also stratified and non-stratified rocks on the basis of their formation. Give a few examples of each.
- What relationship is explained by rock cycle between the three types of rocks?
- Each intrusive igneous formation has its extrusive equivalent just as each rock has its metamorphic equivalent. Elucidate.
- Give a single term for each of the following :
 - A hot sticky molten material.
 - Very deep-seated intrusive rock of igneous group.

(iii) Miscarried volcano under the earth's crust.

(iv) Thin vertical and horizontal magmatic intrusions in the country rocks.

8. Classify the following rocks into sedimentary, igneous and metamorphic :
 (i) trap, (ii) basalt, (iii) dolerite, (iv) quartzite, (v) coal, (vi) anthracite coal,
 (vii) limestone, (viii) chalk, (ix) marble, (x) clay, (xi) shale, (xii) gneiss,
 (xiii) schist, (xiv) sandstone, (xv) granite and (xvi) rock salt.
9. Describe the significance of sedimentary and igneous rocks from the view point of economic minerals.

Cartographic Work

10. Draw a map of India and show areas of sedimentary, granite and basalt rocks in it. Distinguish the area of very ancient rocks from the remaining portion of the map.
11. Draw sketches illustrating formation of coal, a process of metamorphism and the rock cycle.

Finding Out

12. Collect different rock samples and recognise them.

Further Readings

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CHAPTER 5

Earth Movements, Volcanoes and Earthquakes

IT might be interesting to ask what the physiography of Indian sub-continent would be had there been no earth movements of any sort anywhere since the origin of the earth. In the beginning there were neither mountains, nor oceans, plains or plateaus as familiar to us today. The powerful internal forces operating from within the crust are called earth movements, both slow and sudden. They gave birth to the Aravalli Mountains and later on the Vindhyan ranges rising from the floor of a sea then existing in central India. The volcanoes also existed in parts of India pointing out the eruption of red hot lava over a vast area. Such upheavals or periodical sudden movements were confined to relatively narrow belts. These were followed by slow and quiet movements affecting large areas, forming depressions for being gradually filled up by thick sediments. The sediments were subsequently uplifted into mountains. Thus, a cycle of the two types of these earth movements has continued.

About 120 million years ago, the landmass known as 'Gondwanaland' started breaking because of the earth movements, volcanic eruptions and sea floods all working together. India was a part of this landmass consisting of East Africa, Madagascar, South India, Australia, South Africa, South America and the Antarctica. It was one huge

took its present shape and form about 60 million years ago. After the break-up of South India from rest of Gondwanaland, it was during the last one million years that the chain of Himalayan mountains in the north was raised to its present heights and nature created plains, hills and the adjoining seas.

The sediments which were originally deposited only in horizontal layers are seen to have been tilted, twisted or broken. On the other hand, marine fossils are found preserved in some of them. It clearly shows that several areas which now form parts of the land masses were once beneath the sea, and many others which are now below sea level were once land areas. The submergence of a forest in Bombay harbour, the Mahabalipuram temple now standing in the sea and the sinking of 5,000 sq km to a depth of 4 metres in the Rann of Kachchh in 1819 and a land of about 1,500 sq km raised several metres high, are some of the Indian examples of the unstable nature of our earth. Despite these evidences, it may not always be possible to determine such changes and the continued activity of earth during our life time.

Tectonic Movements

The earth movements which bring about these vast changes are called tectonic movements. The concentration of great

downwards. Without them there would be no differences in elevation on the earth's surface.

The earth movements are divided into sudden movements and slow or secular movements.

Sudden Movements

These are commonly noticed during an earthquake. For example, in the Chilean earthquake of 1822, a part of the coast rose up by about one metre, whereas in the New Zealand earthquake of 1885 some parts of the land rose up by 3 metres. In the Japan earthquake of 1891, a part of the land sank by about 6 metres. The considerable changes in level were brought about by the Assam earthquake of 1951 in Brahmaputra Valley of our country.

Slow or Secular Movements

These movements continue much longer as compared to our life span. The raised sea-beaches along east coast of India to a height of 15-30 metres above sea level are observed. On the other hand, the peat and lignite beds found below sea level in the Sunderban Delta and 10 metres submergence of the forest near the Bombay island are some of the Indian evidences of such movements. The tree trunks of this forest are still standing in their original upright position.

A change in sea level in its advance or retreat with respect to adjacent land brings about world-wide changes in level. The periodical advance and retreat of continental glaciers and ice caps because of global changes in climate are said to have caused them. These movements are relative to each other, the land advancing against sea is termed a negative movement and the sea advancing on land is known as a positive movement.

Vertical Movements

These movements are responsible for a

rise or a fall of a portion of the earth's surface. When a part of the earth's crust rises in relation to surrounding portions, it is known as *uplift*. Conversely, when the sinking of a part of the earth's crust relative to surrounding portions takes place, it is called *subsidence*. These earth movements on a large scale build up continents and plateaus. They do not disturb the horizontality of the strata as they were originally laid down. At the most the strata may be only inclined or tilted.

Horizontal Movements

These movements are responsible for greatly disturbing the horizontal arrangement of layers of rock. They involve both the forces of compression as well as tension.

Tension is the pulling force. Rocks have elasticity and can be pulled apart by forces acting from within the earth. Compression is a force that pushes against a body from directly opposite sides. The rocks also change their shape only when compressed or squeezed. As both these two forces apply horizontally to earth's spherical surface they are known as horizontal or tangential movements. The compression leads to the bending of horizontal layers of deep sediments into a shape known as a 'fold'. The tension is responsible for breaking of rock layers with their subsequent sliding or displacement. It is termed as the formation of a 'fault'. The phenomena is also named as *folding* and *faulting* leading to the building up of mountains.

Folding occurs through compression, that is, when two horizontal forces act towards a common point or a plane from opposite directions. It must be remembered that rocks break if compressional force is applied slowly. If the same amount of force is applied rapidly, they break sooner. Of course, some rocks like limestone break sooner than the others like shale. This is

only when the force is operating near the earth's surface. Deep within the earth, this force tends to cause the bending rather than breaking of rocks. Like the waves on a lake surface, the rocks are thrown into a simple upfold and a downfold forming series of crests and troughs, respectively. After folding, the strata occupy a smaller area of the earth's surface than what the original rocks or rock-forming materials occupied. Both types of simple folds have two limbs along the slope. It is called an *anticline* when the limbs incline in different directions from the top. It is *syncline* when the limbs incline to the same direction into the bottom of the trough.

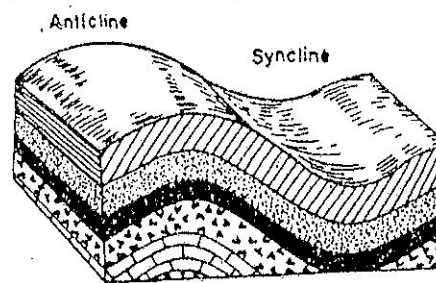


FIG. 5.1 Folding of rocks

Faulting owes its origin to tension, that is, when forces act horizontally in opposite directions away from a given plane or a point. The simple breaks in rocks involving no movements are termed as fractures. On the other hand, when a movement occurs along a rock and breaks, it is called a fault. Sometimes, one side of a fault is vertically thrown upwards and the other side moves downwards. Such a movement on either side of a fracture results in strata lying at a lower elevation on one side as compared to the corresponding strata on the other side. The intense folding of the rock places a great strain on some parts of the folded material. This breaks the strata and gives rise to faults. The faulted strata are sometimes pushed

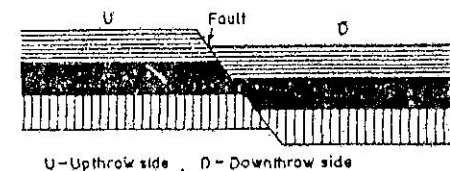


FIG. 5.2 Faulting of rocks

forward far away from the parent strata. Faulting gives rise to relief features totally contrasted from the formations associated with folding. You will read about them in a subsequent chapter. An *escarpment* or the

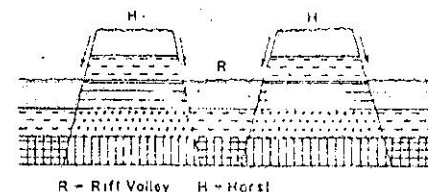


FIG. 5.3 A rift valley and a horst

formation of a highly precipitous slope is associated with the typical landforms caused by the phenomenon of faulting. The escarpments, viz., fault scarps of Western Ghats overlooking the Arabian Sea and of the Vindhyas facing Narmada Valley are primarily due to faulting.

Volcanoes

The volcanic phenomenon is a majestic natural phenomenon which we can neither prevent nor regulate. But the eruption of lava is not alike in the cases of all volcanoes. On the basis of frequency of eruption, there are active, dormant and extinct or ancient volcanoes. The volcanoes which erupt fairly frequently as compared to others are active. The dormant or sleeping volcanoes as one in Barren Island to the east of Andamans in India, are those in which eruption has not occurred

regularly recently. Others which have recorded no eruption in historic times are said to be extinct. Many a time a volcano thought to be extinct may suddenly become active. It has happened in the case of the Vesuvius and the Krakatau volcanoes, thought to be extinct, became suddenly active in recent times.

The island of Krakatau is situated in the Sunda Strait lying between the islands of Java and Sumatra. Its eruption in the year 1883 below off the top of the mountain by an explosion which caused tidal waves about 16 metres high, killing 36,000 people in West Java. The volcanic dust, ashes and smoke spread in about 27 km, the rock fragments and lava rose to a height of about 800 metres. It is reported that the sound of explosion was heard as far as Istanbul (Turkey) in the west and Tokyo in the east. The atmospheric effects of the volcanic dust and gases encircling the globe caused strange sunrise and sunset condition for about three years. Today Krakatau is no more than a low island with a lake inside its crater.

Volcanic Forms

Most volcanoes are an individual mountain or a hill nearly conical in shape. The extent and the height of a volcanic cone depends upon the viscosity of lava erupting on the earth's surface. The top of the cone has a depression known as the crater. It is a funnel-shaped feature with a diameter ranging from a few score metres to two or three or even more kilometres. A crater frequently turns into a lake later on. Lake Lonar in Maharashtra is an example of a crater or Caldara Lake. A volcano is actually a vent or an opening in the earth's crust through which rock fragments, lava, ash, steam and other gases are emitted in the course of an eruption. This solid or molten material accumulates around the vent forming a cone.

Lava blown out of the opening cools quickly in small solid pieces or cinders.

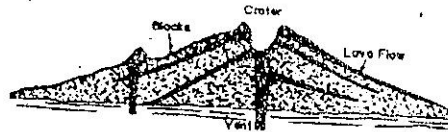
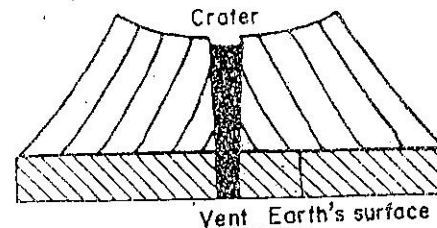


FIG. 5.4 A volcanic cone with a crater

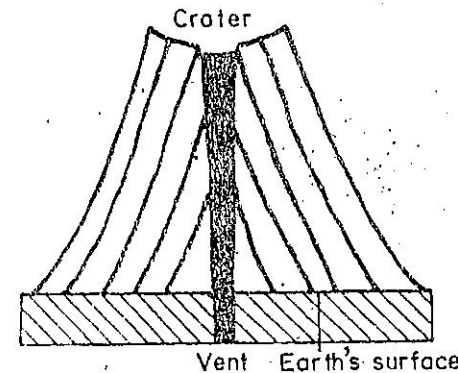
That is why cone and crater are the commonly noticed formations typical of a volcano. The pieces of cooled solid lava collecting around the vent give rise to a cinder cone after a number of eruptions. On the basis of mode of eruption, the hills and mountains having such a cone and crater shape are termed as central type of volcanoes. It is because eruption has taken place through a central hole in the crust connected with the interior through a vertical pipe. The activity in this case is marked by violent explosion as in the cases of Mt. Fuji and Mt. Vesuvius, due to sudden escape of gases through the pipe.

Sometimes, the basaltic lava having low silica content flows out quietly and gives rise to the formation of a shield. The lava flows out quietly around a central opening. In course of time, it builds up a shield-shaped volcano with a wide base and low slope. It cools as thin, like horizontal sheets. Probably the best examples are the shield volcanoes of the Hawaiian islands. The volcanoes that form in mid-ocean are basaltic and rarely reach the sea level. Volcanic plateaus, rather than volcanic mountains, have been formed from basaltic flows on many continents. When lava rises through cracks or fissures in the earth's crust, it covers vast areas. It continues flowing quietly for a long time after intervals. The formation is termed as a fissure-type volcano. The classic example is

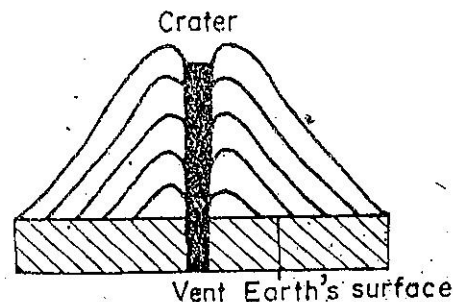
that of Deccan Trap region of Peninsular India.



(a) Cinder volcano



(b) Shield volcano



(c) Dome volcano

FIG. 5.5 Types of volcanic formations

Products of Volcanic Activity

The materials derived from a volcanic eruption are liquid, solid and gaseous in nature. The liquid matter is the lava. The temperature of freshly ejected lava may range between 600° to 1,200°C. The speed of lava flows depends upon its composition, mobility and the slope of the ground. Usually, the movement is very slow and even a speed of 15 km per hour is rarely achieved. But sometimes the speed may be as high as 80 km per hour, making it difficult even for a good horse to run along it.

Very often, the lava in the vertical passage gets solidified. The next volcanic eruption through the pipe is accompanied by explosion of highly compressed gases throwing out blocks of solidified lava from inside the choked pipe. The solid material consists of fine ash and dust particles and angular fragments mostly of lava rock blown up from within the vent.

The gaseous substances are mainly composed of steam, products being hydrochloric acid, ammonium chloride, sulphur dioxide, hydrogen sulphide, hydrogen and carbon dioxide.

Causes and Effects of Volcanic Activity

The fundamental cause of volcanic activity is the conversion of rocks in the deeper layers of the earth's crust from the so-called solid to a molten state of magma. The earthquakes are also responsible for crustal dislocations giving rise to the formation of faults. The release of pressure upon the earth's interior under such dislocations causes the magma to escape to the surface. The exact causes of this activity are still not clearly known. The scientists have gone to some depth inside the craters by taking special precautions. They have been able to bring out the samples of molten lava and recorded the temperatures within the vent.

Volcanoes are no doubt highly destructive to life. It was estimated that a volcano in Mexico in 1943 went on erupting 400,000 tons of lava and cinder a day in its first year. It depopulated an area of over 750 sq km causing huge losses. But volcanic rocks, upon weathering and decomposition, yield very fertile soil. The peasants go on tilling it to get rich harvests despite dangers of recurring eruptions. The ash and dust are found very fertile for fields and orchards, if it does not bury or destroy the vegetation. Volcanoes leave a great deal of scenic beauty in the form of geysers, mineral springs of hot water and crater lakes. They add extensive plateaus and volcanic mountains to our earth. The volcanic activity produces valuable minerals and gases. In regions, where volcanoes have been active, waters in the depth are heated from contact with hot magma. At some of these places, a jet of steam and boiling hot water is emitted at

intervals from small vents. These are geysers and their steam of high temperature is caught to generate geothermal electricity, in areas such as New Zealand, Iceland, Japan, Mexico, Italy, USA and the former USSR on a small scale. Efforts are also being made to harness this energy around hot water springs of Ladakh in India. This type of power is being generated in a number of volcanic districts of the world. The cinders and clots of solid lava known as 'volcanic bombs' are being sold to tourists visiting such areas, for their fantastic shapes.

Distribution of Volcanoes

Out of 486 active volcanoes since the year A.D. 1500, 403 are located in and around the Pacific Ocean and 83 are in the mid-world belt along Mediterranean Sea, Alpine-Himalaya mountains and in the Atlantic and Indian Oceans. If the more ancient

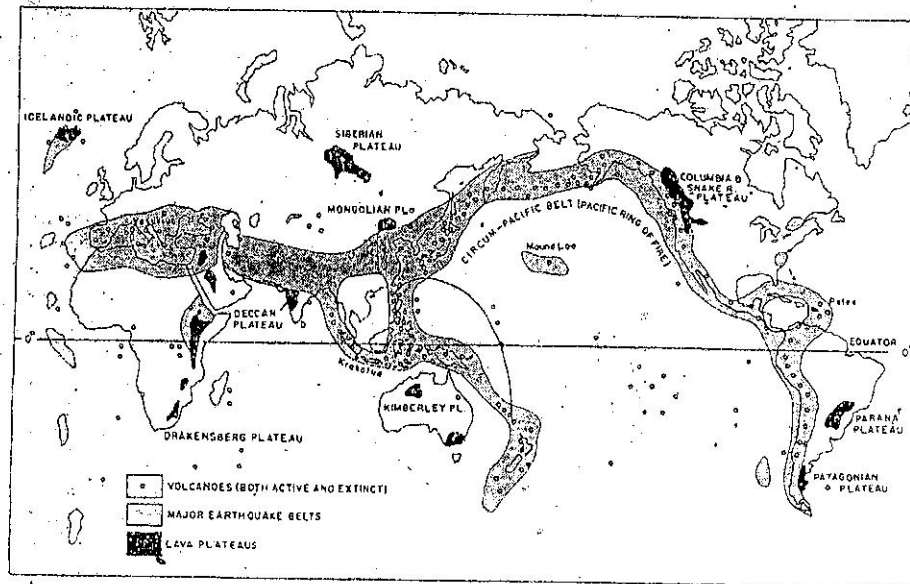


FIG. 5.6 Distribution of volcanoes, lava plateaus and earthquake belts.

known eruptions are taken into account, we get a total of 522 volcanoes. Volcanoes are unevenly distributed over the earth and vast areas have no active volcanoes at all. There are no volcanoes in Australia, in Asia they are largely concentrated in Circum-Pacific region and Africa has a few of them. Thus, the Pacific belt is truly known as the 'ring of fire' because of the largest number of active volcanoes along the coasts of Americas and Asia around this ocean. The Mid-world volcanic belt occupies a second place running from west to east along the Alpine and Himalayan fold mountains and their extensions. Iceland, Sicily and Japan have both active and dormant volcanoes and are counted among the biggest volcanic islands of the world. Africa occupies the third place having one volcano on the west coast, an extinct one in Mt. Kilmanjaro of Tanzania and several such in the Rift-valley lake belt passing through Red Sea and extending upto Palestine in the north. Most of the volcanoes in the world occur along linear belts or lines of weakness marked by intense folding and faulting.

Earthquakes

If a stone is thrown into a pond of still water a series of concentric waves are produced on its surface which spread out in all directions from the point at which the stone strikes the surface. Similarly, any sudden disturbance below the earth's surface, may produce vibrations or shakings in the crust. When rocks break, the particles next to the break are set in motion. It is the movement of one rock mass against another that causes vibrations. Some of these vibrations reach the surface and are known as earthquakes. If the rock-break is deep within the earth, the tremors are too weak to reach the surface or to cause much damage.

Instruments have indicated that there are annually between eight and ten thousand

earthquakes in the world. It comes to about one earthquake every hour. Actually there are many more, because there are no stations to record them over the oceans covering very large surface of our earth. Our earth truly vibrates continuously.

The place of origin of an earthquake inside the earth is called its *focus*. The point on the earth's surface vertically above the focus is called the *epicentre*. Observations have shown that most of the earthquakes originate at a depth from 50 to 100 km and only single earthquake occurs at still greater depths. The shock waves travel in all directions from the focus. On the earth's surface, the shaking is the strongest near the epicentre. That is why the greatest amount of destruction is caused near the epicentre.

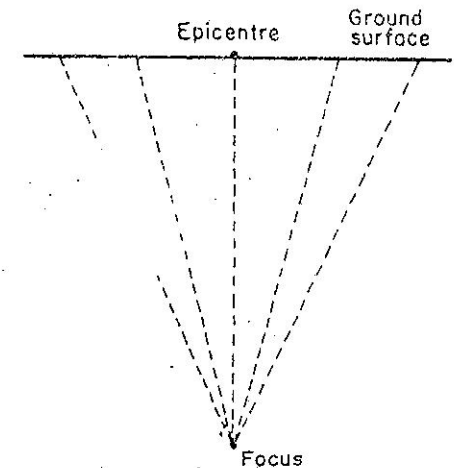


FIG. 5.7 Focus and the epicentre of an earthquake

The earthquakes are studied by a special branch of geology known as Seismology (from the Greek word *seismos* meaning earthquakes). That is why the instrument recording the shock waves is called the Seismograph.

Some minor earthquakes are caused by the collapse of roofs of cavities, mines or tunnels. Others are caused by explosive eruptions of volcanoes and are confined to limited areas. But the major ones are caused by tectonic forces. They are generally due to sudden movements of the crustal blocks or rock strata along faults or fractures in the earth's crust. The strength of rocks is nothing when tectonic forces tend to move them in different directions on opposite sides of the faults. In other words, the energy of these forces moves out and spreads in the form of earthquake waves. The San Francisco earthquake of California in 1906, the Assam earthquake of 1897, the Bihar earthquake of 1934, and the Quetta earthquake of 1935, are examples of this type of earthquake.

Effects of Earthquakes

As mentioned earlier, sudden movements under the earth cause violent earthquakes which are often very destructive. At times, they cause landslides and damming the rivers. Sometimes, they cause depressions forming lakes. Formation of cracks or fissures in the region of epicentre are commonly noticed in the crust. These deep fissures are sometimes many kilometres long and the buildings, people and animals fall into them. The fissures formed during the first shock sometimes close up during the later shocks, but often remain open for a long time. Sometimes water, mud and gases are ejected from beneath the fissure. The gases may ignite the air and water, and mud may flood the surrounding area. Larger areas also subside or sink during very severe earthquakes. Landslides occur during earthquakes in highlands. An earthquake may also lead to change in surface drainage and underground circulation of water. Crustal displacements may close up

the crevices along which water was coming out or they open up new ones. That is why we notice a disappearance of springs in some places and their appearance in others as a result of strong shocks.

Faults, thrusts and folds are associated with earthquakes. It is of interest to mention a thrust of the strata that disrupted several country roads on the floor of a broad valley in Japan during the earthquake of 1891. A tremendous fault occurred during the California earthquake of 1906, running for hundreds of kilometres along the coast.

Perhaps more devastating are fires and a seismic sea waves (called *Tsunamis* in Japanese) which are originated by earthquakes. Instances are not lacking to show that hundreds of thousands of people have fallen victims not directly to earthquakes, but to the fire, flood and sea waves which follow them.

Distribution

About 68 per cent of all earthquakes are observed in the vast region of the Pacific ocean as a 'ring of fire' and is closely linked with the region of crustal dislocations and volcanic phenomenon. Chile, California, Alaska, Japan, Philippines, New Zealand and the Mid-ocean areas have had many minor and major earthquakes in this belt. Mountains here run along the border of continents and nearly parallel to the depressions in oceans. It causes sharpest break in relief which becomes a cause for the earthquakes.

Around 21 per cent of them occur in the Mid-world mountain belt extending parallel to the equator from Mexico across Atlantic ocean, the Mediterranean sea from Alpine-Caucasus ranges to the Caspian, Himalayan mountains and the adjoining lands. This zone has folded

mountains, large depressions and active volcanoes. The remaining 11 per cent of the shocks are recorded outside these two belts. Only a few occur along the fracture in African lakes, Red Sea and the Dead Sea zone.

The earthquakes in India are at present mainly confined to the Himalayan region and its foothills. They are also felt in the Ganga Valley. But the earthquakes in Koyana Dam region in 1968 and Latur in 1993 in the Deccan Tableland came as surprise. This region was otherwise considered to be free from earthquakes. Scientists believe that while in the former case reservoir caused cracks in the rocks, in the latter case the movement of the Indian plate might have been the cause.

There have been a number of violent earthquakes in India in historic times. The Kachchh earthquake (1819), the Assam earthquake (1897), the Kangra earthquake (1905), the Bihar earthquake (1934), the Assam earthquake (1950) and the Latur earthquake (1993) are some of the well-known examples.

Man is unable to prevent earthquakes, all he can do is to take steps for safety. More seismic stations can be established for issuing warning to the people of coming earthquakes. The suitable building structures need to be encouraged in earthquake areas. Sometimes our own observations, like sudden changes in atmospheric conditions and abnormal behaviour of animals, can help us to forecast the arrival of an earthquake.

EXERCISES

Review Questions

1. Answer the following questions :

- (i) Why is our earth called an unstable earth ?
- (ii) Why is volcanic activity often associated with mountain-building ?
- (iii) Compare and contrast folding and faulting.
- (iv) What is a volcano ? Give example of different types of eruption material.
- (v) What is an earthquake and how is it caused ?
- (vi) Describe the salient features of volcanic topography.
- (vii) What relationship do you find between earthquake and a volcanic phenomenon ?
- (viii) In what ways earthquakes affect the earth's surface ?
- (ix) What caused earth quake in Koyana and Latur in South India ?

2. Write short notes on :

- (i) A rift valley, (ii) Focus and the epicentre, (iii) Fissure, (iv) 'Ring of fire', and (v) Tsunamis.

3. Describe systematically the vertical and horizontal movements originating in the earth's crust. Give relevant references from Indian sub-continent.

4. What is volcanic activity and what are its probable causes ?

5. Write short notes on the following :
(i) Extinct volcanoes, (ii) Negative movement, (iii) Central type volcano, (iv) Faulting, (v) Vertical earth movement, and (vi) Folding.
6. Define in short the following terms :
(i) Anticline, (ii) Syncline, (iii) Horizontality of the strata, (iv) Tectonic movement, and (v) Seismology.
7. Classify various types of earth movements. Describe how each contrasting from the other, giving examples from India.

Cartographic Work

8. On a world map, indicate major mountain systems, volcanic areas and areas where earthquakes are common. Compare the occurrence of each form of these crustal movements.

Finding Out

9. Find out information on : (i) recent earthquakes in India, and (ii) in other countries of the world. Also prepare a report supporting with a map locating the places of occurrence and the areas affected by earthquakes.

Further Readings

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Wadia, D.N. *Geology of India*, London : Macmillan & Co., 1961.

CHAPTER 6

Landforms and their Significance

A STUDY of landforms is important for understanding their influence upon man's life. It includes the description of the characteristics of various forms of land surface. We can better appreciate the wonders of physical landscape by learning about its formation. The landforms are classified on the basis of the way they have been shaped and the main features by which they are recognised.

Rocks and the Associated Landforms

In general, type of rocks have a great influence on the landforms developed in an area. The relatively stronger rocks like granite, quartzite and limestone have greater hardness and are not easily worn down. They give rise to upstanding mountains and hills. The soft rocks like shale, clay or loose sand form bluffs or knolls but turn into plains and valleys upon their weathering. The sedimentary rocks form plains or lands with gentler slope unlike the crystalline rocks. But in highly wet and warm climate, even hard limestone gets rapidly weathered, while in dry deserts it keeps standing steep and high. That is why the climate of an area and the time taken in wearing down of rocks also influence the landforms.

The joints in rocks are another important feature determining their strength. These are lines of weakness and appear as cracks in rocks. Through them

corroding agents like water enter even into an impermeable rock. It increases the scope of their decay by chemical processes. Even a hard rock of great physical strength like granite is attacked by the action of water, ice or frost through its joints. In other words, the non-porous and impermeable granite or slate behave as permeable if they are crossed by joints. The ice or frost inside the cracks of such rocks breaks them into angular blocks in the long run. On the other hand, a rock like chalk or coarse-grained sandstone is porous and an easy victim to the process of chemical decay by water.

Under favourable climatic conditions, permeability and porosity both help the rock in its rapid chemical decay. Where hard but permeable limestones and softer but impermeable shales occur together, the former stand as high plateaus and ridges and the latter as valleys or lowlands.

It is interesting to observe that a layer of moderately resistant rock between two layers of non-resistant rock forms a ridge but the same rock between very resistant rock forms a valley. Thus, the same rock will produce different landforms depending upon its location, the type of the climate, agents of weathering and the rate of erosion and weathering. The two different types of rocks under a uniform climate may also produce varying landforms because of the difference in structure and composition of rocks. Thus,

the relation between types of rock and relief is complex because of differences in climate and the stages of their erosion.

Each rock is still said to develop a typical landscape of its own. Granitic upland is observed commonly in the form of big size domes as in Telengana and Rayalseema regions of Andhra Pradesh. As soon as the overlying rocks are removed, these domes appear on the surface. They result into what are known as 'tors' on removal of the easily weathered material. Limestone upland characterised by bold cliffs and caves is marked near Dehra Dun.

Classification of Landforms

There are three major landforms—mountains, plateaus and plains.

Mountains

An uplifted portion of the earth's surface is called a *hill* or a *mountain*. In our country, a mountain is differentiated from a hill, when its summit or top rises to more than 900 metres above the base. Those with less than this elevation are called hills. In course of time the mountains are worn into hills. On the basis of their origin or mode of formation, the mountains are classified as structural or tectonic, residual or dissected and volcanic.

Structural Mountains

All great mountain systems of the earth are of this type. Such systems are hundreds of kilometres wide and thousands of kilometres long. Many of them lie near or parallel to continental coastlines. Both the fold and the block mountains are included in this type.

1. Fold Mountains

The major mountains of the present day

including the Alps in Europe, the Rockies of North America, the Andes of South America and the Himalayas of Asia are structural fold mountains. The granitic core of such mountains is surrounded by metamorphic rocks, merging with sedimentary layers along the margins. The phenomenon of folding and faulting is most complex in the central areas of these mountains. The fold is recognised by the bending of rock-strata, up and down or sideways. These young fold mountains are still rising under the influence of the earth's tectonic forces. They are known for variety of rock structures, deep gorges and the high pyramidal peaks. The rock-strata of these mountains was originally laid down as sediments in narrow elongated sea or lake basins termed as *geosynclines* or the earth's depressions. The material was squeezed and uplifted by horizontal compressional forces. The sedimentary material today marked on tops of such high mountains or marine fossils found inside such rock-strata point out the uplift of the deposition filling up the geosynclines in distant past. These depressions made the weak zone of the earth's crust as the sediments deposited in them were displaced and deformed greatly over the ages. The Himalayan ranges were formed over millions of years in three major phases at the site of one such marine basin called the Tethys Sea. The third phase of uplift is still not over. The formation of folds has taken thousands of years to rise in a series of arches and troughs, or in getting pushed over each other. That is why highly compressed and altered rocks of different ages are found in these young mountains. The Himalayan landforms consist of long loops of three main ranges of increasing heights on going from south to north, converging frequently to form knots. As it took seven

million years for them to rise slowly to their present heights, the great rivers have been struggling constantly to cut their way across high mountains. This has made deep canyons and narrow gorges further separating one valley enclosed within the ranges from another. The landforms have been modified considerably by glaciers, trapped by snowfields in greater Himalaya and worked over by rivers and streams. For studying them in detail they have been sub-divided into different sections from west to east for which you may refer to your Indian geography textbook.

The Urals, the Appalachians, the Tien Shan and the Nan Shan were formed during an earlier mountain-building period. The highlands of Scotland and Norway and the Sayan and Stanovoy mountains in Russia are of still earlier period. The Aravallis, however are considered to be one of the oldest mountains on the earth. All these older fold mountains have been denuded for a long time. This has made them much less rugged and of lesser heights as compared to the newer fold mountains. This oldest tectonic mountain of our country forms the border of central highlands running from west to east. At present they extend from south-west of Delhi to near Ahmedabad for a distance of about 800 kilometres. Near Delhi it retains its rocky character and is known as Delhi ridge. At its southern end, it is just 60 metres high and scattered buttes are the remains of the mighty range. Today only in central and southern parts it acts as a hill barrier. Because of its abrupt rise from the plains and its hard quartzite rock, it is unfavourable to man. In central part it divides into a number of parallel folds enclosing plateaus. The rounded Abu hills of granite rise to 1,722 metres which is the highest peak. While effects of erosion have reduced them to low heights and to

peneplain at some places, an uplift is also observed at others.

During compressional movement, two crustal blocks move towards one another or one block moves towards a stable block. In either case the strata between two blocks is bent into folds or cracks into faults.

Inside the earth, pressure on sufficiently plastic sediments is so great that they bent without cracking. Such folds appear on surface on subsequent exposure. The latest theory explains the formation of such mountains with the help of the concept known as plate tectonics. The whole earth has been divided into six major plates. Each plate consists of the crust and upper mantle extending to 100 kilometres of depth from the surface. It may be of interest to know that on collision of one plate with another, their edges are pushed up into such great mountain ranges.

2. Block Mountains

These mountains are formed when great blocks of the earth's crust may be raised or lowered during the late stages of mountain-building. During the uplift of structural mountains, sometimes magma flows upward into the crust. On its cooling and hardening beneath the surface, it contracts and the overlying rock may crack into large blocks moving up or down. An intense folding of rocks is generally followed by faulting of strata due to horizontal force of tension. The land between the two parallel faults, either rises forming *block mountains* or *horsts*, or subsides into a depression termed as a *rift valley* or *graben*. Such a vertical movement is also taking place in many of these mountains. An old fold mountain may also be left as block mountains due to continuous denudation. These mountains have flat tops, steep fault scapes and the

subsided portions between parallel fault are flat-bottomed. The Vosges in France, Black Forest mountains in Germany and Salt Range in Pakistan are cited as typical examples of block mountains. River Rhine in Europe flows through a rift valley. The great rift valley of the world runs for about 6,000 kilometres from East Africa to Syria through the Red Sea. In India some scientists are of the view that Narmada river flows through a subsided or faulted basin between Vindhya and Satpura which stand as block mountains to its north and south, respectively. Assam ranges have also undergone a great amount of faulting though we don't have such typical examples.

3. Volcanic Mountains

As these are formed by the accumulation of volcanic material, they are also known as *mountains of accumulation*. The matter is thrown out and deposited around the crater to form a mountain. If the lava is thin and basic in its composition, it spreads a long distance forming a flatter cone of gentler slope and of low elevation. If it is thick and of acid composition, a small volcanic cone sharply pointing out is the result. Sometimes lava is thrown out along with ash and cinders. Such a volcanic cone is termed as ash and cinder cone. Mount Mauna Loa in Hawaii islands is an example of the former type. Mt. Fuji Yoma of Japan and Mt. Popa in Central Myanmar are examples of the latter one.

4. Residual or Dissected Mountains

They owe their present form due to erosion by different agencies. That is why they are also known as *relict mountains* or *mountains of circumdenudation*. They have been worn down from previously existing elevated regions. Hills like the

Nilgiris, the Parasnath, the Girnar and Rajmahal in India are examples of this type. But Nilgiris got their present height as a result of subsequent uplift. According to some authorities all mountains of the Peninsula with the exception of the Aravallis are relict mountains. They form those portions of old plateau which have escaped weathering. The residual mountains stand alone in the surrounding area reduced in height. They may be part of an upland eroded to form a number of hills.

Plateaus

A plateau is an elevated area generally in contrast to the nearby areas. It has a large area on its top unlike a mountain and has an extensively even or undulating surface. A steep cliff is usually marked along the side of a plateau away from the mountains except in the case of one surrounded by high mountains. It is along this slope that uplift takes place. The rocks of the plateau are layered with sandstones, shales and limestones. It is this arrangement of the strata which gives it a large even surface. But an inclined or a tilted strata may also become flat through continuous wearing down. The great Deccan Plateau with its slope towards east is a tilted plateau in our country. Very often, rivers and streams cut out deep valleys and canyons in a plateau region. It changes its smooth topography into a dissected plateau. The plateaus are of three types on the basis of their situation (i) intermontane, (ii) continental, and (iii) piedmont plateaus.

Intermontane Plateaus

The plateaus which are partly or fully enclosed by mountains are known as intermontane plateaus. The highest and extensive plateaus of the world, such as Tibet, Bolivia and Mexico are of this

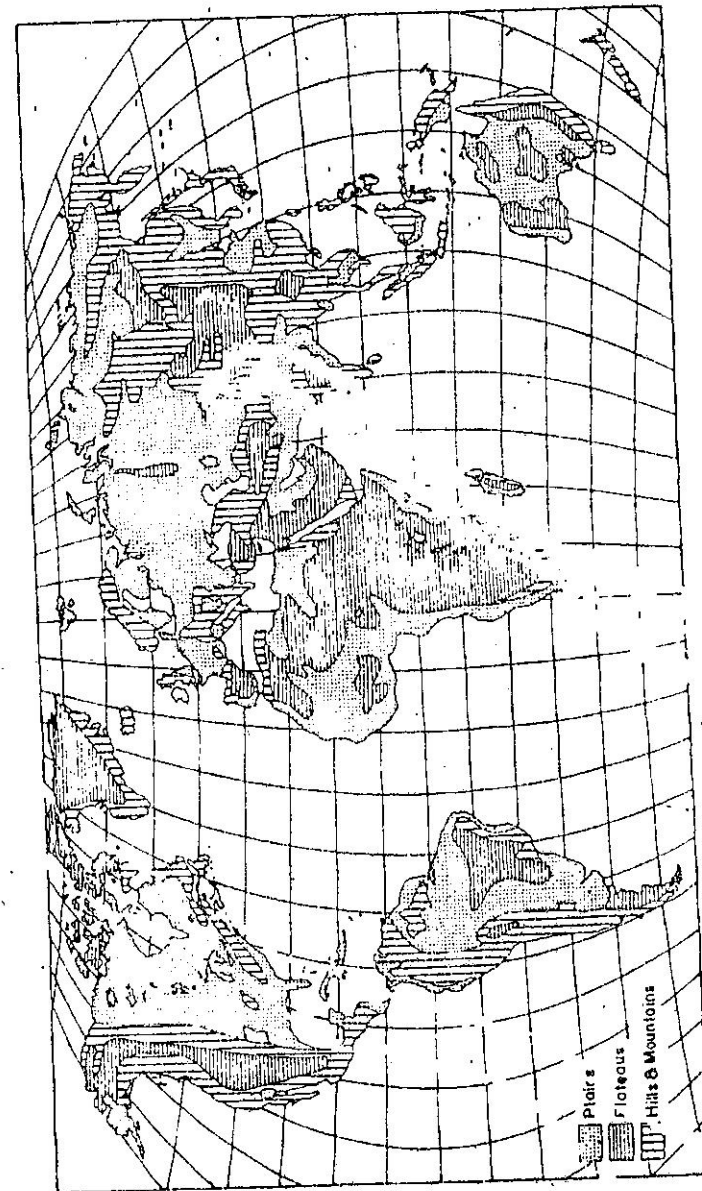


FIG. 6.1 Distribution of major landforms

category. These are the results of the mountain-building process which was accompanied by a vertical uplift of the adjoining enclosed lands.

Piedmont Plateaus

Situated at the foot of a mountain, they are bounded on the opposite side by a plain or an ocean. The plateau of Malwa in India, those of Patagonia in Argentina and the Appalachian in United States are some of the examples. These are also called the plateaus of denudation because areas which were formerly high have now been reduced in elevation by various agents of erosion.

Taken together, all plateaus have been caused either by the great vertical tectonic movements resulting in uplift of the strata, or by the spreading of basic lava sheets over an area.

Continental Plateaus

They rise abruptly from the lowlands or from the sea. They are the result of a continental uplift producing large tablelands like the plateaus of Brazil, South Africa, West Australia, Chota Nagpur and Shillong. Their heights vary from 600-1,500 metres.

Sometimes a plain or a low-lying area is vertically uplifted and gives rise to a plateau. In India, plateaus of Kaimur, Rohas, Ranchi and Karnataka are of this type. The Potwar plateau of Pakistan also falls in this category.

When lava spreads out to cover the pre-existing land surface, a lava plateau is formed which is also called a plateau of accumulation. The horizontal sheets of lava flow have trapped the original topography varying in depth from 1,200-1,500 metres over large parts of Maharashtra and the adjoining areas in Deccan. The Snake River plateau in north-

west United States, Antrim plateau of northern Ireland are also good examples of such volcanic plateaus.

Indian Plateaus

The Peninsular India has a number of big and small plateaus. Deccan portion of the Peninsula has three broad sections consisting of the lava plateau of Maharashtra, and the Karnataka and Telangana plateaus of uplifted continental type. Extensive plains flat or rolling at all levels and bordered by scarps are the main features of plateau landscape.

The north-eastern part of the old landmass of Peninsular India is occupied by a number of south Bihar plateaus, collectively known as Chota Nagpur plateau. It has the plateaus of Ranchi, Hazaribagh and Kodarma sloping northwards and all built of granitic gneiss. Ranchi plateau is 700 metres high in its upper part. There are big rounded granitic hills and the elevated terraces of older flood plains in it. Much of it is a peneplain or almost reduced to a plain. It is deeply dissected around its edges forming steep scarps known as ghats. River Damodar, with a number of coal fields and newly built reservoirs, flows to the north of it in a faulted trough. The other two plateaus of Chota-Nagpur are to the north of it. There are also set of peneplains at various stages. They are flat except along their outer edges. On the west of Ranchi Plateau, stands a group of higher plateaus recognised by their flat laterite-capped tops known as 'pats'. The pats rise to over 1,000 metres and have steep scarps around their edges. They are the remnants of older and more extensive peneplains. While Damodar basin of Chota Nagpur is known for its major coal fields, the other plateaus have earned a name for mica, bauxite and a host of

mineral wealth. In the Himalayas, we have the highest plateau of a different category in Ladakh.

Plains

A relatively flat and a low-lying land surface with least difference between its highest and lowest points, is called a plain. The plains are usually lowlands. Some of them may be smooth, while others are slightly rolling. A plain may be as low as 30 metres to the east of Mississippi river near the Appalachian range and as high as 1,500 metres above sea level to the west of the river. The great northern plains of India are just at tide level near the mouth of Ganga river, and attain an average of 200 metres height in Punjab. The Kashmir lake plain in our country reaches an average height of 1,700 metres above sea level. Plains can be placed according to their position and surface relief but are better classified on the basis of their mode of formation. They are sub-divided into structural, erosional and depositional plains.

Structural Plains

These plains are formed by the uplift of a part of the sea floor usually bordering a continent, that is, the continental shelf. The coastal plain lying between the Appalachian Piedmont Plateau and the Atlantic coast of south-eastern United States is an example of an uplifted coastal plain. On the other hand, there are structurally depressed areas which make up very extensive lowlands on the earth. The underlying horizontal beds of rocks are relatively undisturbed by the earth's crustal movements. Such plains include the great plains of Russian platform, the great plains of U.S.A. and the Central lowlands of Australia.

Erosional Plains

These are formed when an elevated tract of land, for instance, a mountain, a hill or a plateau is worn down to a plain by the process of erosion. Over long ages, the higher land is levelled down into a sort of plain. The surface is hardly smooth and forms almost a plain termed as a peneplain. These are found in river, ice and wind eroded regions. Northern Canada, northern Europe and west Alberta are examples of such ice-eroded plains. Many hollows scooped out by ice are now filled up by lakes. Parts of Sabana in Africa are wind-eroded plain surfaces. The rivers by widening their banks and lowering the higher land between them have eroded parts of the Amazon basin into stream-eroded type of plains.

Depositional Plains

These plains are formed by the filling up of sediments into depressions along the foot hills, lakes and sea. The huge amount of this material is transported by natural agents like running water, waves, wind and ice. It starts the process of levelling up of the depressions. The deposition of sediments eroded and brought down by large rivers forms riverine alluvial plains. The Indo-Ganga Plains in the Indian sub-continent, the Huang He Plains of North China, the Po River Plains or Lombardy in north Italy and that of Nile River are examples of some of the great alluvial plains. The alluvium when deposited at the foot of mountains forms piedmont plains like those of 'Bhabar' in Uttar Pradesh along the Himalaya. When it is deposited along the middle course of great rivers, extensive flood plains like those of Bihar in our country are formed. The great loads of sediments are spread over every year during floods. The delta plains are formed along

the mouths of rivers like Ganga under favourable situations. Depositional plains resulting from glacial deposition make a drift or a till plain consisting of unsorted sands and gravels carried by ice. Plains of north-western Eurasia and that of Ladakh to the east of Shyok River and north of Chang Chenmo River are such glacial plains. Winds carry very fine dust particles known as loess from barren surfaces of interior deserts to the adjoining areas. The loess plains due to this deposition are observed along normal margins of west Rajasthan, Turkmenistan and north-western China. The deposition of sediments in a lake basin gives rise to old lake plain, or what is called as a lacustrine plain. The Valley of Kashmir, the Imphal basin in the Manipur hills are examples of this type. Their fertile soil have made them areas of good agriculture and thick population within mountains.

There are coastal plains also resulting from the deposition by sea waves and winds driving the beach materials landwards. It results in the formation of marine swamps, mud flats and tidal lowlands. A good portion of the coastal plains of Belgium, Netherlands and of Palestine are examples of plains emerging as a result of deposition.

Indian Delta Plains

The great plains of north India stretching in front of the Himalayas include Ganga Delta on the east and the Arid Plain of Rajasthan on the west. The Delta Plain in West Bengal and Bangladesh becomes so flat and so low that a mere 6 metres rise of sea level would submerge Calcutta and its surroundings. The old and new delta of the Ganga and the Brahmaputra rivers occupies the whole of this basin in Indian sub-continent. Like any other great deltas of the world, it has a network of

distributaries near its seaward face and shallow tidal depressions near Calcutta contain salt water. The streams get choked and are dying in western part of the basin to the west of Hoogly or Bhagirathi branch of the river. The streams are more active eastwards and silt is ever renewing in forested swamps of Sunderbans and in Bangladesh. The proper delta has been shifting eastwards and most of it falls in Bangladesh. Its formation is the result of more silt brought by slow-moving waters of the streams and less of it removed by tides and ocean currents. An enormous amount of silt brought here by the rivers and the alluvium left by flood water adds to the flatness of delta plain. It spreads far and wide, as both the carrying capacity and cutting power of the streams is considerably reduced. The delta of the combined Ganga-Brahmaputra rivers lies between their Hoogly-Bhagirathi and Padma-Meghna branches. The deltaic plain has new mud, old mud and marsh. The fine alluvium is very fertile for growing a number of crops like paddy and jute every year.

The east coastal plains of India have smaller deltas of Mahanadi in Orissa, Godavari and Krishna in Andhra Pradesh, and most important Kaveri river in Tamil Nadu.

Significance of Landforms to Man

Each of these landforms has a different significance for man. Mountains have for long been protecting man, isolating his habitations and restricting his movement. Those defeated by invasions in the past found protection in them. This barrier effect is not absolute. Passes in mountains permitted military invasions. The explorers and settlers could also come in through them from time to time. This allowed exchange of goods and ideas

among people of either sides of the passes. Though mountains like the Himalayas make natural frontiers between nations, the actual boundary line is no longer agreed upon for all the times. The national interests have come to value even for barren mountains. Thus, mountains no longer provide security to nations as they did in the past.

Agriculture in mountains is mostly marginal or uneconomic, as good cultivable soil is found at a few spots and it is easily washed away from the slopes. But now horticulture is being practised successfully even on lands not suitable for high value agricultural crops. The valleys between the mountains are being intensely irrigated and cultivated. The difficulty of transport has also been reduced by spending more on construction and maintenance of roads. This costly development has broken the tendencies of isolation to a great extent.

The forests and the scenic grandeur have for long been source of attraction for people from outside. The salubrious climate and mountain scenery have encouraged tourists. Old temples and uniqueness of local cultures have been other attractions. These have been economic resources for fostering tourism. Although mountains continue to be scarcely populated on account of natural handicaps, a great increase in the number of people in valleys and in bordering plains has denuded forests of their wealth. The development of hydro power potential from the waters of snow-fed perennial rivers is now making it possible to exploit local resources in the mountains. Alpine and Scandinavian countries of Europe and Japan in Asia have been able to offset some of their difficulties by development of cheap water power. The mineral wealth of less rugged fold mountains have also been

exploited in recent years.

The response of man to plateau regions is different because of marked variations in topography, soil and climate. The plateaus like lava plateaus are rich in agriculture because of the fertile soil. The bleak intermontane or eroded piedmont plateaus are poor in this respect. Some of the old plateaus are rich in minerals as their crystalline rocks are exposed for extraction of minerals. The rivers have rapids along the steep edges of a number of plateaus. It has made possible the generation of hydro power. For long the higher parts of plateaus in tropical regions have provided coolness for Europeans to settle and practise plantation agriculture. The benefits are still being enjoyed by plateau dwellers in such areas of India, East Africa and Brazil. The plains particularly in tropical (excluding equatorial belt) and temperate regions are teeming with people. Their flat surface, deep and fertile alluvial soil, nearness of water-table for irrigation, easy means of communication and transport have made them the home of two-thirds of world's population. They have got the advantages of plenty of cheap labour, raw materials, a big consumer market and easy accessibility. They are areas of rich agriculture particularly in warmer climates providing a longer growing season. In land, river navigation much before the age of railways favoured towns and industry to grow. Easier mixing and movement of people made them cradles of civilisation. But plains suffer from lack of minerals. Great additions in their population is posing a problem. The low plains face destruction by floods every year by increase in the volume of river water during rainy season. The wealth of plains have often attracted invasions in the course of history.

EXERCISES

Review Questions

1. Answer the following questions :

- (i) Why plateaus are regarded as storehouses of minerals?
- (ii) Why man's occupancy of plains is the oldest and most intense?
- (iii) What are the resources found in the mountains? How some of their handicaps are being removed?
- (iv) List different types of depositional plains giving examples of each type.
- (v) List different conditions under which a block mountain is formed

2. Distinguish between the following :

- (i) The piedmont alluvial plain and the delta alluvial plain.
- (ii) The piedmont plateau and the intermontane plateau.
- (iii) Block and fold mountains.
- (iv) Eastern and Western Ganga Delta.
- (v) Plateaus of continental uplift and of continental accumulation.
- (vi) The great plains of the United States and of Northern Europe.
- (vii) The residual mountain and a volcanic mountain.

3. Give one term for each of the following :

- (i) Mountains formed due to horizontal tensional forces.
- (ii) A tract once elevated, now worn down to almost a plain by erosion.
- (iii) A lowland with few inequalities on its surface.
- (iv) A plain formed by uplift of the continental shelf.

4. Make out correct pairs from the two columns :

- | | |
|--|---------------------------|
| (i) The Valley of Kashmir | Intermontane plateau |
| (ii) The Tibetan plateau | Young fold mountains |
| (iii) Fuji Yoma | Lacustrine plain |
| (iv) The Ganga Delta | Piedmont plateau |
| (v) The Himalayas and the Alps | Old fold mountains |
| (vi) The Nilgiris and Mt. Parasnath | Piedmont plain |
| (vii) The Appalachian plateau | Relict mountains |
| (viii) The Ranchi and Karnataka plateaus | Alluvial plain |
| (ix) The Bhabar plains | Uplifted plateau |
| (x) The Urals and the Aravallis | Mountains of accumulation |

5. Describe the influence of different rocks with different structures on the landforms with special reference to varying climates.
6. Describe in detail the origin and characteristics of young Himalayan mountains. Illustrate with diagrams.

Cartographic Work

7. Draw sketches illustrating major landforms.

Finding Out

8. Try to find out the meanings of landforms of first, second and third orders. Give examples from India.
9. Collect information both from this book and from additional sources regarding different Indian plateaus—their origin, geological history, relief and the resources.

Further Readings

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CHAPTER 7

Soils

A BULK of human population still continues to live where good soil helps it to grow food. Wherever deep and fertile soil is found and climate is favourable for cultivation of crops, the area grows not only food crops but also non-food crops used as raw materials in industries. Such are the mid-latitude grasslands and the alluvial plains. On the other hand, the shallow and infertile soil along mountain and hillsides is far less productive. Despite changes introduced by industrialisation most of the world's population still live where the soil furnishes them food. It was the rich soil of river valleys like those of the Indus and the Nile which attracted man to settle down in their plains. These were the cradles of ancient human civilizations. Their good soil and the river water encouraged an intensive use of soil laying the basis of a flourishing agriculture and human habitations. It makes soil of a great significance to mankind as a basic natural resource although it forms only the thin uppermost layer of our land surface. Truly speaking, it occupies a significant place in the biosphere or life zone of the earth. This has made it important to find out the differences in soils from place to place over the globe and how they are formed.

Soil is a mixture of many solid, liquid and gaseous substances. It forms the topmost layer of earth's crust. It has both the non-living and living matter like

mineral particles, decaying plant remains and insects living together with countless bacteria on its organic matter. Soil holds water. This moisture is taken in by the roots of plants. There is air in the open spaces within the soil containing more of carbon dioxide and also oxygen and nitrogen. The combination of all these nutrients in the body of soil is the source for plants to grow. As the plants die, the nutrients re-enter the soil and are again used by the living plants. Such a cycling of nutrients over long ages keep our soils living for human utilisation. Soil is the final product of the interactions between the weathering of underlying rock, the climate, plants and the activities of millions of insects and earthworms. All these physical, chemical and the biological activities build up the soil layer over a long period of time.

As the nature of rocks, physical characteristics of land, climate and the plant cover vary from place to place, a great variety of soils is found over the globe. Their diversity supplies us a variety of agricultural products, grasses and the trees. But one to two centimetres thick stable soil cover may take thousands of years to form under the most favourable conditions. It takes very short time to lose it. It is left to man to see that the precious material is not lost to us. The rush of water takes little time in washing it off a slope, more rapidly if it has no vegetation

cover. If it is a light and loose soil, severe wind blow during a dust storm can carry it off in no time. A greater run-off along the slope during a torrential rainfall carries sheets of soil or makes furrows in it. The soil losses in any of such ways are known as erosion. The erosion of soil is found all over the world. But it is localised except in equatorial and tropical regions of heavy rainfall and great drought. The misuse of soil by man over the ages has also made its erosion more menacing. You may find out examples of areas which have thus lost their top cultivable soil.

Even in flatlands like India's Ganga

Plains, the soils get exhausted and less productive every year if right methods of cultivation are not employed to keep up their productivity. It is given to man to adopt all measures to conserve the soil resource. Once destroyed or degraded, the loss in terms of agriculture and plant cover is more or less permanent. It is in this sense that soil is truly a non-renewable resource.

The Soil Profile

Soil is initially the product of weathering of the rocks when it consists of the fresh

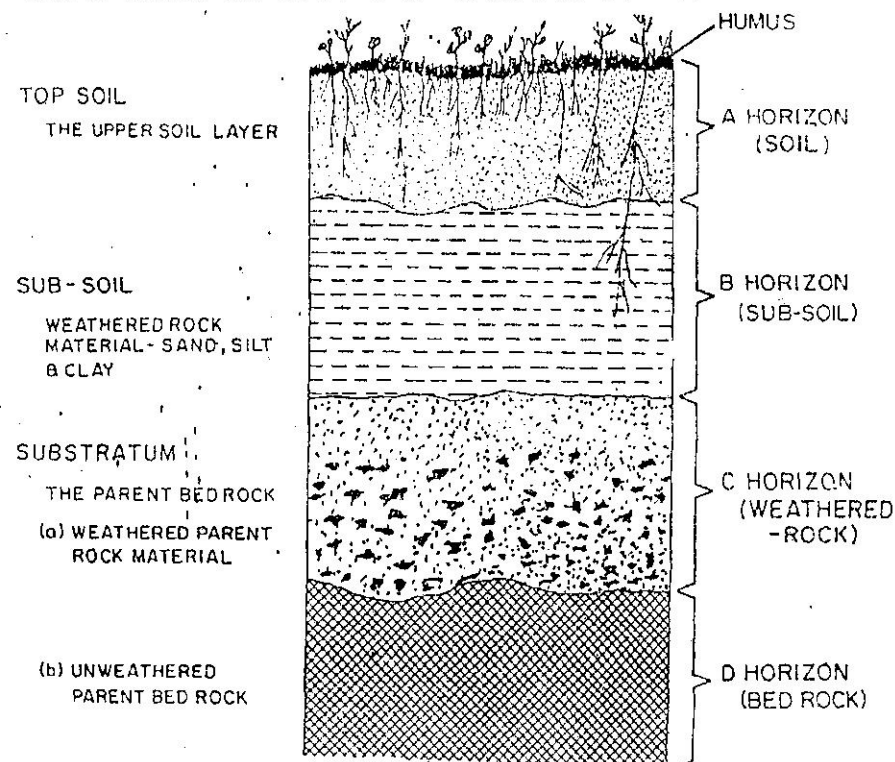


FIG. 7.1 Soil horizons and bedrock

weathered material, lacking in organic matter. It may only be transported by river, wind or glacier reducing it to finer sediments. The soil profile consists of the weathered material derived from the rock. But the bedrock itself does not form a part of it. Neither it has any horizontal layers termed as horizons. A really developed soil profile results if the weathered material keeps lying at a place for a fairly long time. During the slow process of decomposition of the bedrock and addition of the organic material, its horizontal layers, one above another, are formed. A soil profile generally has three main horizons in it—true soil at the top, sub-soil and the bedrock apart from it. Each horizon is quite distinct from the other by its own physical and chemical composition, and organic contents produced during the long process of soil formation.

Properties of Soil

Each soil type has physical properties like its colour, texture and the structure. They largely depend upon the nature of the bedrock from which they are derived. The colour, in itself, is unimportant. But it tells of how the soil has been formed and of what it is made. Texture refers to the mixture of different soil particles grading from coarse into fine grades of gravel, sand, silt and the clay. Soils are called sandy when they have a large proportion of sand grains. Clayey soils have a large proportion of clay particles and a little of sand. Soils with fairly equal proportions of sand, silt and clay are called loams. Loams are termed as sandy loam, silty loam and the clayey loam, depending upon the preponderance of sand, silt or clay, respectively.

Soil texture also indicates whether the pore or open spaces between its grains are

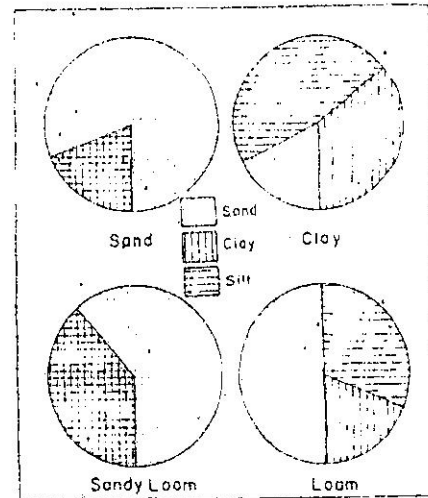


FIG. 7.2 Major soil textures

small or large. The fine clay soil has small pore spaces and hence the rate of passage of water to its lower levels is very slow. In other words, this type of soil is more water-retentive. In sands, pore spaces are large enough to transmit the water downwards rapidly. They have very low capacity to retain or hold water. Thus, the texture determines the ability of the soil to retain water and to drain it to lower levels. Loamy texture, having an admixture of all the three, is the best for plant growth and its ploughing is easier at the same time. Purely sandy soil is considered light and shifting while pure clay is heavy for ploughing. The latter forms cracks on drying and becomes very sticky on getting wet. Out of loams, sandy loam is the most favoured by farmers. The property of structure refers to the way soil particles are arranged when broken up for cultivation. The grouping of soil grains in the aggregate gives rise to nut-like granular,

crumbly, blocky, platy, plastic or columnar structures. Soil structure also influences its erodibility, ease or difficulty in ploughing and the rate of moisture absorption.

All soils have their own chemical properties. On this basis, they are said to be acid, neutral or alkaline. Soils with low lime content are called acid and those with high lime content are called alkaline. The water in the soil contains dissolved carbon dioxide together with acids derived from decaying organic matter. Soluble salts are produced during chemical breakdown of rocks. The air in soil's pore spaces contains atmospheric gases when these are not saturated with water. The decaying remains of plant and animal life forms is termed as humus. It gives a dark brown or black colour to the soil. Natural vegetation also responds to chemical properties of a soil. Many plants which like acid soil will not grow in soil with strong lime content and alkaline in nature.

The physical and chemical attributes of soil differ greatly from one site to another even within a local area. There are also differences observed vertically from one horizon to another in a soil profile.

Factors of Soil Formation

There are five soil forming factors—bed-rock or the parent material, local climate, plant and animal organisms, elevation, and the relief, i.e., topography and the time over which soil has developed. Out of

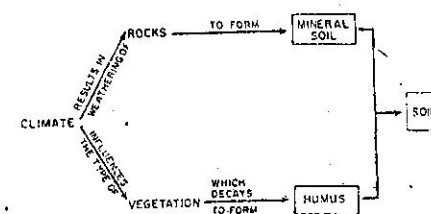


FIG. 7.3 Soil factors

these, the parent material and the climate are the two most important factors on a large regional scale. While the climatic and biological soil-formers are called active agents, the parent material, topography and the time are considered relatively passive agents.

The underlying rock containing minerals is called the parent material from which a soil is derived. But it is not necessary that the soil in a locality must be lying over the rock from which it has originated. The parent material gets broken into pieces and is slowly decomposed by mechanical, chemical and the biological weathering. It is the parent rock which furnishes a soil with inorganic mineral particles. Although, all the three main types of rocks supply this material to soils, it is greatly derived from the sedimentary rocks. The rates of physical and chemical weathering of parent rocks are different depending upon their structure, degree of hardness and the climate. Some rocks weather easily and others decay at a slower rate. Such properties make some rocks like shale, a better soil-former than the limestone which is a poor soil-former. You may find out instances of different types of rocks and the rate of their weathering under different set of conditions. Faster the rate of weathering as in a hot and wet climate, faster is the rate of soil formation.

Climate of an area is such a major factor that over a long period, it tends to reduce differences caused by the parent materials. That is why two different parent materials may develop the same soil in one type of climatic regime. Likewise, the same parent material may produce two different types of soil in two types of climate. The crystalline granites produce laterite soil in relatively moist parts of the monsoonal region and non-laterite soils in arid

margins. The heat combined with the rate of alternation between wet and dry intervals of monsoon climate is the basic cause. Hot summer and low-rainfall develops black soil as found in some districts of Tamilnadu, irrespective of the parent rock. In the Rajasthan Desert, both granite and the sandstone under uniformly arid climate have given sandy soil, poor in organic matter.

It is the seasonal distribution of temperature and rainfall which determines the type and effectiveness of weathering, quantity of water seeping through the rocks and type of organic matter acting upon them.

Plant and animal organisms consisting of trees, shrubs, grasses, mosses, bacteria and the animals play a very important part in converting a young soil into mature one. Dead plants provide humus, which is consumed by other forms of life like bacteria. In humid tropical climate, bacterial activity is intense. Consumption of humus is so much that soils are left poor in it. In cold climate, bacterial activity is limited and the soils are rich in humus. Bacteria also changes nitrogen from air into a chemical form which is usable by plants. That is why bacteria is termed as nitrogen fixing agent. Humus also enriches the soil, quickens the weathering of minerals in the process of soil formation. Small organisms like earthworms live in millions in the soil and help in reducing its grains to small size and in mixing the mineral and the organic matter. Burrowing animals like ants, rodents, termites and some birds move the surface soil downwards and the sub-soil from its lower horizon upwards. The mixing of two soil layers helps in improving the texture and its aeration.

Topography or the local site factor also affects the deposition of soil, degree of its

erosion and the rate of run-off of the water. Only a thin and coarse soil is left on steep rocks on which it is formed. That is why it is called a *residual soil*. The elevation and the nature of slope also influence the rate of weathering and the drainage of water. Much of the soil is carried from the hill slopes by transporting agents like rivers, wind and glaciers towards the valley bottoms and flat-lands as alluvium. Such *transported soil* is very fertile because it is derived from different kinds of rocks from over a wide catchment. The deposition of soil sediments goes on undisturbed for a longer time making it lie deep on flatlands. The degree of erosion on them is less as compared to the hill slopes. At the same time flatland soils may be under-drained or poorly-drained because of gathering of water during floods. On gentle slopes, new soil is derived from the parent material but it takes a long time to balance the soil which is removed by erosion. The fresh river alluvium or glacial till are soils of the young stage. They have a greater control on the parent material and have a poorly developed soil profile. *Mature soils* are developed over a long time reflecting the influence of climate and of organic matter. They have well-developed soil profile. It tells us the influence of time factor which changes a young soil into mature and sometimes into old and sterile one. It is followed by the change in the physical and chemical characteristics of soil and also the degree of its fertility. Indirectly man is also influencing the formation of soil by way of its retention. Increasing urbanisation by him activates the large and small earthflows down the moderately steep slope because of massive constructions. The clay layers saturated by waters of heavy rains or melting snow may start creeping or slowly sliding down more as a result of excavation or removal of support by man.

Such a soil moss descends upon houses, highways and forests.

Soil Classification

Soils are classified differently, but the two main zonal groups are the *Pedalfers* and the *Pedocals*. These are further divided into twelve major soil types all over the globe. These are found over large areas forming latitudinal belts in the world. We can easily mark a correlation between world's soil map, maps of climatic regions and of natural vegetation.

precipitation throughout the year. There is strong leaching (downward movement of salts), slow breakdown of needle leaves and slow formation of humus. The bacterial activity is also limited. The soils are acid, infertile and of limited value for agriculture. But grey-brown podsollic soils found in mid-latitude deciduous forest belt in Western Europe and north-eastern USA are relatively less leached, have fair humus content and remain fairly fertile by manuring, fertilization and crop rotation. They have been well used for dairying and mixed farming.

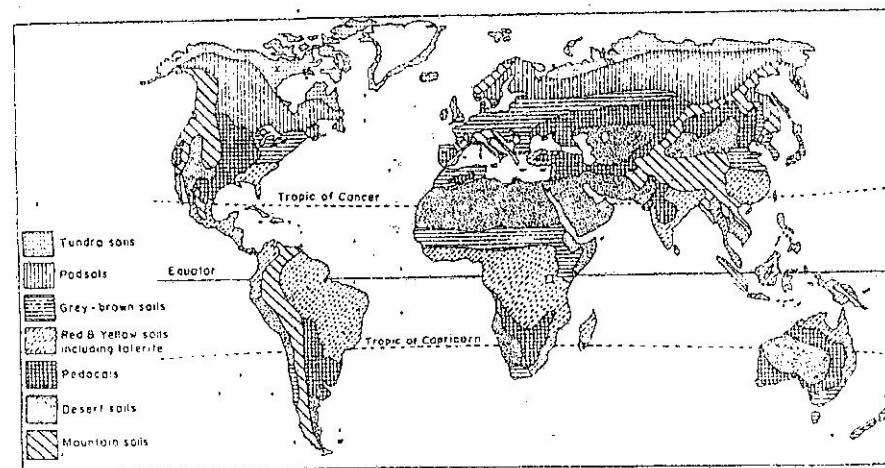


FIG. 7.4 Distribution of major soils in the world

Pedalfers

Such soils are found in humid climates extending from high-latitude coniferous forests, mid-latitude deciduous forest lands to low-latitude tropical forests and grasslands. Podzols of ash-grey colour are found in high-latitude coniferous forest belt having very long cold winters, short cool summers and a moderate

The red and yellow tropical pedalfers in low-latitudes experience high temperatures and seasonally wet conditions. The soluble minerals are leached but iron content gives them this colour. A greater bacterial activity consumes more and leaves little humus in them even when there is plenty of organic matter. They suffer equally from calcium deficiency. These soils are acid and are soon exhausted unless kept

fertile by application of fertilizers.

Pedocals

The arid, semi-arid and the sub-humid zones in the world have pedocals group of soils. These are rich in calcium and mineral salts. It is due to greater evaporation that both the soluble minerals and water move upwards. They have developed in the mid-latitude grasslands, the steppes and the prairies or in and around deserts both in the temperate and tropical regions.

The black earths or chernozems are one of the richest soils of this group. They are rich in humus, rich in calcium, unleached and have a crumbly or nut-like structure. The climate of the region is of dry winters and of early moist summers. These are fertile soils requiring little fertilizing even when used year after year. They need a little irrigation because of their greater moisture holding capacity. The steppes of Ukraine, the central part of the USA, Central Africa, South America and Australia have become famous for growing big harvests of grain crops like wheat and oats or for livestock grazing on these soils. The prairie soils of USA are nearer to pedocals although found in moist parts of temperate grassland regions. They are poorer in lime than the black earths, have good crumbly soil structure and are highly fertile.

The desert soils are grey in colour in temperate region and red in hot deserts of the tropics. These are regions of low-rainfall, high temperatures and high evaporation. The soils are unleached and alkaline but very much lacking in humus because of little vegetation found in such areas. The calcium carbonate gathers close to the surface forming a hard pan. The soil horizon is poorly developed. They are cultivable only where the texture is fine, salt is less and irrigation water is available. There are patches of sterile or barren soil in the belt of pedocals under dry steppe-like climatic conditions. It is known as 'usar', the term collectively applied to all kinds of saline and alkaline soils in the plains of north India, particularly in Uttar Pradesh. The clay soil with bad or imperfect drainage in low-lying plain areas is found covered with a great amount of *reh* (white, greyish or ash-coloured salt) in dry periods. As the salts are transferred from below, even canal irrigation helps in their accumulation in such areas. The bad drainage or water logging also deteriorates the irrigated soils of dry areas. The saline soil patches are dissolved under muddy water during the rains. One finds no vegetation on such soils and it gives a hard rock-like appearance during dry spells. The soil fertility decreases if the salt content is increased and making its reclamation difficult and costlier.

EXERCISES

Review Questions

1. Answer the following questions:

- Which are the physical attributes of a soil?
- How is soil different from a rock?
- List the active and passive factors of soil formation.

(iv) What is humus? How is it formed?

(v) What are the functions of soil for which it needs to be conserved?

2. Give one technical term for each of the following:

- Surface material on land having distinctive horizons.
- Zonal soils most widely distributed in cold temperate climate.
- A redish and highly leached soil of humid tropics.
- A zonal soil group requiring no fertilization, even if cultivated year after year.
- The name of a soil which keeps lying on the rock from which it is derived.
- The name of a soil which has no relation with the parent rock upon which it lies.

3. Define the following terms precisely:

- Alkaline soils
- Loams
- Podsoils
- Soil drainage
- Soil leaching
- Pedocals

4. Describe the principal characteristics of the podsoils, chernozem and desert soils.

5. Distinguish between the following:

- Black soil of Ukraine and Black soil of Maharashtra plateau
- Soils of the dry and wet climates.

Finding Out

- Find out information on different types of soil erosion prevailing in various parts of India. What are its causes and the suggested remedies?
- Collect the samples of different soils from your local area carefully. Write a short essay on the properties of each type.

Cartographic Work

- Show areas affected by soil erosion on a map of India.

Further Reading

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CHAPTER 8

The Underground Water

THE rain-water or snow-melt that neither runs off along the surface nor evaporates but sinks into the ground is known as *underground water*. Such ground water in some quantity is present everywhere in soil, sub-soil and the bedrock. A great amount of it finally reaches the sea after moving through underground channels. Thus, it becomes a part of the hydrological cycle by which process the rain-water originating from the sea finally returns to the sea, where it comes from.

The part of the surface water moves downwards through pores between mineral grains or cracks between rocks. The water-holding capacity of a rock material depends on the pore spaces known as its *porosity*. Another property of rocks is their *permeability*. It stands for their capacity to allow water to pass through them. The pore spaces or openings if connected with each other make a rock permeable. If these openings are not interconnected, the rock is impermeable and water cannot move through it. Thus, a permeable rock is always porous or pervious but a porous rock is not always permeable. There is no further movement of underground water when a non-porous strata is reached. The smaller the openings, the greater is the friction and slower is the movement of underground water.

The rocks that have large connected

pores through which water can flow freely are known as *aquifers*. The aquifer is a water bearing rock and refers to an underground reservoir of water. Loose sedimentary rocks like sand and gravel, and the jointed limestone are tapped for their underground water because of their high permeability and water-bearing nature. The clay is porous but becomes watertight and has a low-permeability just like the compact quartzite or the granite. The latter have poor aquifers and are unsuitable for depending upon them for the ground water.

It is significant to note that underground water provides soil moisture for plant growth, supplements water in streams and lakes, and is frequently used for human consumption.

The Water Table

The pore spaces of the rock are all filled with percolating water at a certain level below the ground. The zone of pervious or porous rocks fully bearing this water is called the *zone of saturation*. The level below which the rocks are completely saturated with water is called the *water table*. The water table thus, separates the saturated zone from the unsaturated zone lying above it. The pore spaces in the latter zone are filled only with air except during rains. The rain-water seeps or percolates through the unsaturated layer till it is held in the saturated zone at some depth.

In other words, the water table is the vertical distance of ground water level from the surface, whether close to the surface or far below it. The deepest level the water table attains is the permanent water table, whereas seasonally it rises very close to the land surface for short periods as during heavy rains. The zone below the permanent water table is the zone of permanent saturation, and that between the highest water table and the permanent water table is the *zone of intermittent saturation*.

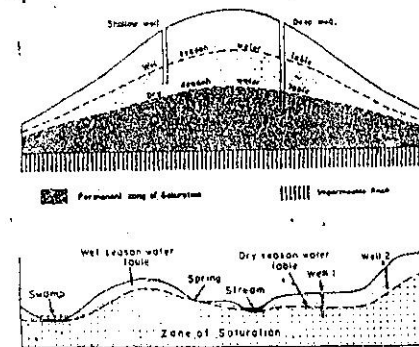


FIG. 8.1 Water table

The water table reaches the surface in springs, permanent rivers, lakes and swamps. It is deeper on hill tops and in dry areas than in valleys and the humid regions. That is why water wells drilled close to hill tops are drilled through more rock than those in valleys. Usually, it is lower in summers especially during droughts. The wells dug up only upto the seasonal water level go dry while those reaching below the permanent water table are sources of perennial water supply.

The ground water table in any area is thus controlled by its climate, the changes in rainfall from time to time and the character of underlying rocks. It also responds to surface relief by following a

slope or the gradient during its movement from higher to lower elevations.

Wells

The wells are man-made holes dug into the earth's surface in order to get the underground water for irrigation or for human consumption. A well can just be a pit dug to reach a permanent water-bearing layer or to make use of a seasonal percolation for a short time. While digging a well, care is needed so as to avoid piercing the impervious layer below the aquifer. Otherwise, the ground water goes in the pervious bed lying lower down. The tube-well is in the form of a shaft sunk into the ground upto permanent water-bearing strata at a greater depth. If top aquifer has little water, the well can be bored to the next aquifer, may be lying still below.

A special type of well in which water rises automatically under the pressure of a column of water to the ground surface, either through a natural or man-made hole, is known as an *artesian well*. The name *artesian* is derived from the province of Artois in France, where the first well of this type was sunk. Artesian wells occur in regions which fulfill certain conditions. The rocks must have a synclinal or tilted structure. There should be a layer of permeable rock lying between two impermeable rock layers. It is necessary that the permeable rock should be exposed at the ground surface, so that rain-water soaks into it. There should be sufficient amount of rainfall in the area where the permeable rock is exposed at the surface. Thus, the water flows through the permeable rock in the same way that water moves through a pipe.

The biggest area of artesian water in the world is the Great Artesian Basin of Australia, situated in the eastern interior of

the continent. It covers an area of about 1,500,000 sq km.

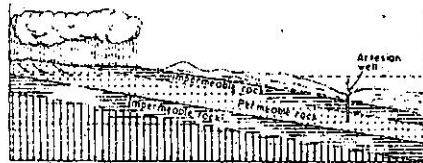
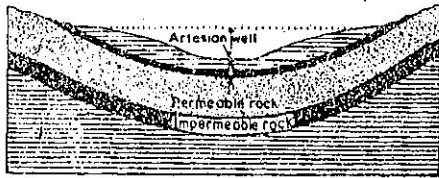


FIG. 8.2 Artesian wells

Artesian wells are rather uncommon in India. However, a number of successful artesian borings have been carried out recently in the alluvial tracks of the Gujarat State, in Pondicherry and in the South Arcot district of Tamilnadu State. A special mention may be made of the Neyveli lignite coal-mining area of this district, where the mining operations were hampered on account of the flooding of the mines by the ground water rising under artesian conditions. Artesian conditions are also known to exist here and there in the alluvial plains of northern India.

Springs

Springs are places where a flow of water rises to the surface through natural rock opening under hydraulic pressure from the depth. The aquifer is either exposed at the surface or underlies a pervious material. The water of springs will be either in plenty or scarce, depending on the area

and thickness of the aquifer or its volume of water.

A spring or a chain of them are common at the junctions of permeable and impermeable rocks and also where the joints, fissures and porous rock beds allow a free escape of water to the surface. The ground water accumulated in the middle of the permeable rock forms a head of water which emerges as a spring as aforementioned junctions on the hillside.

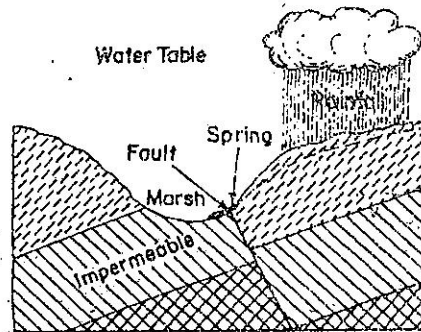
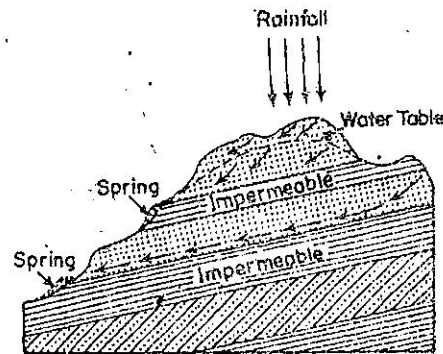


FIG. 8.3 Formation of springs

They are marked along the foot of a scarp in the hills upto which level the rain-water percolates and cannot move farther down the impermeable strata.

Where the impervious bed is in the form of a flat depression, the spring flows out at the bed's lowest point which reaches the surface. This is known as a *pit spring*, while the former is the *scarp foot spring*. In hard and solid rock the ground water percolates mainly through its fissures. The aquifer's fissures can reach the surface on slopes of hills or valleys and water flows out of them. This type is called a *fissure spring*. If there is a dyke having impervious material exposed at the surface and pervious strata lies on both sides of it, the ground water comes out at the surface of the dyke in the form of a spring known as *dyke spring*. A spring also comes into existence as a result of faulting. In this case, a permeable bed comes to rest against an impermeable bed due to faulting. The water accumulates in permeable rock and flows out in the form of a *fault spring*, where the fault plane intersects the ground surface.

Hot Springs and Geysers

They generally occur in regions of active or recent volcanism. The ground water comes in contact with the heated or

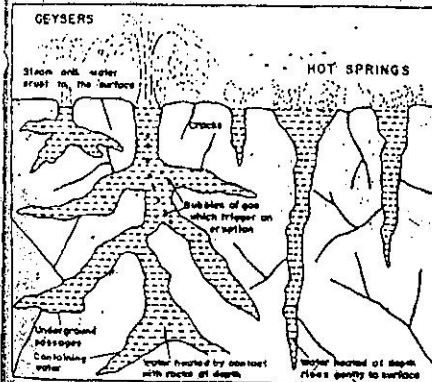


FIG. 8.4 Hot springs and geysers

superheated steam inside the earth and emerges at the surface either as a hot spring or as a geyser. A *geyser* is hot spring in which water is forced up by steam pressure at intervals. As the opening at the surface is small, water and steam cannot flow out regularly. The steam pressure forces the water to shoot out through the openings. It is also believed that geysers originate probably owing to the sudden expansion of superheated steam gathered in underground cavities.

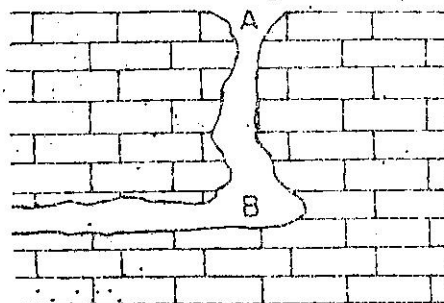
The word geyser comes from *geysir*, the Icelandic name for the Great Geyser of this island in which water rises to a height of about 60 metres. The word *geysir* is actually an equivalent of gusher. Some geysers erupt at regular intervals. For example, the Old Faithful in Yellowstone Park in the Rockies in the United States used to erupt once every 65 minutes. The three most important areas where hot springs and geysers occur are : Iceland, the parts of the Rockies of the United States and the North Island of New Zealand. In the Yellowstone Park alone there are more than 100 geysers and about 4,000 hot springs. Mineral springs are hot springs in which minerals are dissolved and waters have unusual colour, taste or the odour. The cold water springs are found in the Himalayas, the Western Ghats along Konkan coast and the Chota Nagpur uplands. Hot springs are also found in many parts of our country, especially in the hilly or mountainous parts of Jammu and Kashmir, as well as in Himachal Pradesh, Bihar and Assam. Some of the important hot springs are the Manikaran (Kulu), Tatapani (Shimla) and Jwalamukhi (Kangra) in Himachal Pradesh, Rajghr (Patna) and Sitakund (Munger) in Bihar, Gangotri and Yamotri in Uttar Pradesh, and a few others in the Thana District of Maharashtra.

Groundwater as an Agent of Gradation

In dry regions mainly in highlands composed of limestone-like rocks on a large scale, 'Karst' topography is caused by the movement of underground water as an agent of gradation. It is so named after a province of Yugoslavia on the Adriatic sea coast where such formations are most noticeable. Limestone is a rock readily soluble in rain-water carrying carbon dioxide from the atmosphere. The water percolates through highly developed system of joints and fissures running through the massive limestone strata. The surface water rapidly runs off as it disappears down the rocks and almost whole of it circulates underground. Aided by mechanical corrasive and solution of limestone in water, it gradually goes on removing entirely the beds of rock through which it has been percolating downwards. This action is stopped only when the underlying impermeable strata is ultimately exposed over which the streams and reservoirs are always full of water. The surface springs flow out only from the base of limestone lying along the junction of the underlying impermeable rock. The characteristic features of limestone topography are the sink holes, swallow holes, dry and blind valleys and the caverns.

Sink hole is a funnel-shaped depression which has an average depth of three to nine metres and in area it may vary from one square metre to more. In areas of limestone, dolomite or gypsum, sometimes the whole surface is dotted with these holes. For instance, in the limestone plateau of Kentucky in the United States of America, their number is well over 60,000. In India, these are observed along the southern edge of Meghalaya's limestone strata. The sinks are developed by enlargement of the

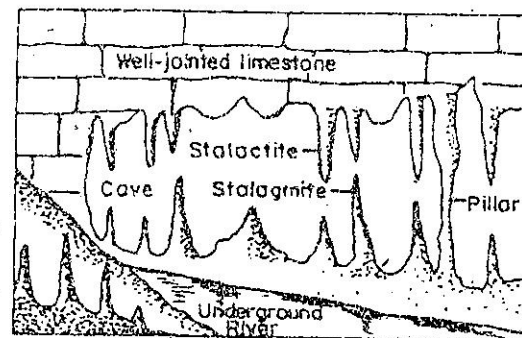
cracks found in such rocks, as a result of continuous solvent action of the rain-water. The surface rock gradually subsides creating deep and wide sinks on the hillsides and valley floor indicating the intense activity of underground water. Where these sinks are numerous the area is very dangerous for construction work and for laying of railway tracks or construction of roads. Sometimes, streams disappear into them leaving their beds dry, and sometimes springs fed by the lost stream may flow out from the sink. As time goes on, the sink holes join with each other creating huge depressions. The beds of the dry streams appearing in this way are known as *blind valleys*.



A - Sinks on the surface of limestone rock
B - Swallow holes at the bottom of a funnel shaped sink

FIG. 8.5 Sink holes and swallow holes

Swallow holes are cylindrical in shape lying underneath the sink hole at some depth. The surface streams that often sink suddenly disappear underground through them. It is so, because these holes are linked with underground caves in rocks through vertical shafts. They justify their name by virtually swallowing the sub-surface streams which may re-appear from rock openings further down the slopes



INTERIOR VIEW OF A LIMESTONE CAVE

FIG. 8.6 Stalactites and stalagmites

Caverns: As the course of underground water erosion proceeds, the groundwater drainage is fully developed and a network of caverns and chambers linked up by galleries or passages are formed. The channels carrying water flow through these passages or reservoirs of water are found inside the chambers. A large limestone cave formed by solution due to underground water is named as a *cavern*. The mammoth cave of Kentucky, for example, has about 50 km of such continuous passages. It has 200 chambers with a total length of over 250 km and its big room is over 30 metres high. The floor of such caves are usually found strewn with rock waste which has fallen from the roof. They are usually adorned by beautiful upstanding pillars and natural rock bridges. In India such caves are observed near Chetrapunji in Khasi hills and near Dehra Dun in Uttar Pradesh. The caves of Kotamrasi in Bastar District of Madhya Pradesh are among the few caverns in India. The biggest of their chambers so far explored is over 100 metres long and the maximum height of the ceiling is about 12 metres. They have icicle-like stalactite and stalagmite

formations.

The water, containing limestone in solution, seeps through the roof of the caverns in the form of a continuous chain of drops. A portion of the drop hangs on the roof and on the evaporation of water, a small deposit of limestone is left behind contributing to the formation of a *stalactite*, growing downwards from the roof. The remaining portion of the drop falls to the floor of the cavern. This also evaporates, leaving behind a small deposit of limestone aiding the formation of a *stalagmite*, thicker and flatter, rising upwards from the floor. Thus, limestone is deposited both on the roof and the floor of the cave. As this process grows, both the stalagmites and the stalactites often join together to form a complete pillar known as a *column*. Despite all these beautiful underground formations collectively known as 'Karst topography', the surface of the rock is bare, bleak and is divided by sharp jagged crests in the course of time. The smooth layers of the limestone is cut into zigzag fashion by deep ruts made by the water moving down and thereby dissolving the rock.

EXERCISES

Review Questions

1. Answer the following questions
 - (i) What factors determine the water table? Discuss them briefly.
 - (ii) How do you explain the sudden disappearance of rivers in limestone regions?
2. Distinguish between the following carefully :
 - (i) Stalagmite and Stalactite
 - (ii) Hot spring and Geyser
 - (iii) Permanent water table and Seasonal water table
 - (iv) Artesian well and Ordinary well
 - (v) Porosity and Permeability
 - (vi) Sink hole and Swallow hole
3. Define carefully the following terms :
 - (i) Aquifer, (ii) Saturated and unsaturated zones, (iii) Dyke spring, and (iv) Fissure spring.
4. What are the essential conditions for developing "Karst Topography"? Explain the formation of main features characterising such a landscape.
5. How does the underground water become an agent of gradation. (Refer to its work of erosion and deposition).

Cartographic Work

6. (i) Locate major areas of wells and the artesian wells in a map of India. Locate the hot springs in it carefully.
- (ii) Consult topographic sheets of the Survey of India depicting springs and wells. Draw sketches and label them with suitable captions.

Finding Out

7. (i) Find out how drinking water is supplied in your small local area. Investigate the cause for its shortage, if any. Find out the depth of water table and account for its variation from one site to another at different times during the year.
- (ii) Collect informations about caves in India from direct and indirect sources.

Further Readings

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CHAPTER 9

The Process of Gradation

THE tectonic or earth-building forces give rise to major landforms like mountain ranges, plateau blocks and faulted depressions. There are erosive forces originating on the surface of the earth which destroy the elevations and fill up the hollows of the earth's surface. In other words, the tectonic or internal forces level up and the erosive or external forces level down the earth's surface. As a result of the two opposite forces, the surface ultimately attains a common level or a grade. All the processes which tend to bring the surface of the lithosphere to such a common level are known as process of gradation. A surface thus reaches a grade when there is neither erosion nor deposition any more.

The present landscape is temporary because as soon as a portion of the earth's crust is raised, it stands exposed to a variety of destructive forces.

Degradation and Aggradation

Gradation as spoken above is achieved by simultaneous processes of degradation and aggradation. The general wearing away of the land surface by external agencies or forces is known as *denudation* or *degradation*. The term *denudation* has been derived from the Latin word *denudare* means 'to lay bare'. It includes the result of weathering, erosion and transportation. The term 'weathering' means the weakening, breaking-up, rotting

and the disintegration of rocks at or near the earth's surface. It starts as soon as a rock is exposed to the influence of weather. The disintegrated material, the products or the results of weathering do not involve any motion except the falling down of the material by the force of gravity. Weathering is followed by *erosion*, which is a process of scraping, scratching and grinding of the surface rock. It includes removal or transportation of the weathered rock material from one place to another. The act of erosion is performed by a number of natural agents like running water, ground water, moving ice, wind, waves and currents of the sea. These agents use the eroded material as cutting tools to carve up and shape the landscape. Erosion is a mobile process unlike the static process of weathering. It keeps the weathered rock material in motion by picking it up and transporting it.

Aggradation or *deposition* means the filling up of the depressions on the earth's surface. The agents of aggradation are the same as those of erosion. In other words, each agent has its erosive as well as depositional role in changing the landscape slowly, but surely.

The Types of Weathering

The disintegration of rocks by mechanical process is called the physical or mechanical weathering and their decomposition by chemical changes is

known as chemical weathering. The two processes are not clearly separable in nature although one or the other may predominate under different climatic conditions. Sometimes, both the mechanical and the chemical changes are involved in a third type of weathering known as biological weathering.

Mechanical weathering takes place without changing the rock's chemical composition. The minerals in the rock are only separated from each other in this process. Although, it is most rapid in sedimentary rocks yet it does not spare even the harder granite and the marble. It is observed that old buildings and monuments built of the latter rocks become weather-beaten and are also not long-lived. This weathering is common in deserts, cold or hot, under the influence of rapid changes in daily temperature. The exposed and bare rock surfaces become hot and expand during the great and intense amount of sunshine. Also, during winter nights when the temperature may fall close to freezing point, results in their contraction. As different minerals in the rock expand and contract at different rates, it creates a series of cracks or joints in their outer layer, splitting them into angular blocks, and reducing them to fragments and pieces. The debris moves down the mountain slope and goes on gathering at its foot as *talus* or *scree*. The alternate expansion and contraction of outer rock layers being more than the inner ones, the outer layers are subsequently peeled off from the main mass of the rock in the form of concentric shells. This kind of weathering is called *exfoliation*. Sometimes, the weathering of the lower portion of the blocks followed by the removal of the weathered material leads to the development of a balanced or a perched block of the rock. Such a rock is seen

placed as precariously balanced over another granite block near Jabalpur in Madhya Pradesh. The granite domes of Mahabalipuram, particularly 'Krishna's butter ball' are examples of mechanically weathered coarse-grained granite. The fine-grained basalt and dolerite do not disintegrate so readily as the coarse-grained rock, the dark coloured and the multi-coloured rocks also get rapidly heated than the light coloured ones resulting in rapid breaking. But the projecting edges and corners of fine-grained as well as light-coloured rocks are rapidly rounded off by weathering owing to their greater exposure to the atmosphere. Almost all rounded forms of dolerite blocks of rocks in Singhbhum District of Bihar are due to this process.

In areas of severe cold climate as in the higher and inner Himalayas, the alternate freezing and melting of water inside the cracks in rocks split them into fragments. It is known that 9 cubic inches of water turns into about 10 cubic inches of ice. The conversion of water into frost or ice increases the volume of water. This phenomenon, also known as *frost weathering*, develops a strong force in widening the crevices in rock by physical destruction over a period of time. The work goes on every winter in high latitudes and at high altitudes. Its magnitude is indicated by a continual increase in the formation of series over the mountain sides. The rocks are also destroyed by plants, animals and activities of man. The long and tenacious root fibres of the plants work down into the cracks of rock. Even roots of shrubs and trees reach deep into them and dislodge large blocks from the cliffs. The burrowing by earthworms, ants, rats and the like, make channels through the rocks and contribute to their destruction. The excretions of

many of them provide acids for a gradual decay of the rock. The quarrying, mining, deforestation and indiscriminate cultivation of land by man are other contributory causes. Such biological action may be physical or chemical in nature.

The processes that cause rocks to decay, i.e., to decompose instead of disintegration are known as *chemical weathering*. As a result of the action of air and water, the minerals in rocks undergo a chemical change. The chemical reactions between rock and water are rapid if both the temperature and the moisture is high as found in humid tropics. The rain-water contains carbon dioxide in solution. It has an acidic effect and it reacts with rocks to form new chemical substances. This is the process of *carbonation* and is noticed in lower humid latitudes. The decaying organic matter also forms acid, some of which gets dissolved and carried away in rain water. The atmospheric oxygen in rain-water also unites with mineral grains in the rock especially with the iron compounds. This results in decomposition of the rock and it starts crumbling. This is the process of *oxidation*, changing the colour of the rock into red, yellow or brown as we see in rusting of iron. The chemical union of water with aluminium-bearing minerals detaches the outer shell of such a rock through the process of *hydration*. The product left behind is the residue of sand and clay. Some minerals as rock-salt and gypsum are removed by the process of *solution* in water.

The mechanical action of rain in loosening the rock particles is small than its chemical action. The acidified water brings about the decomposition of minerals more readily in the rocks. These are means by which even a hard crystalline rock is made to break-up into its constituent mineral particles. How they

work, we cannot see. The few tiny cracks on the rock surface caused by temperature changes expand with weathering, fragments fall away from corners and edges and gather at the base of slopes. The smooth surface of rock becomes rough and we see black or rusty stains on it. All these results and products of weathering point out the strength of processes wearing away the rocks. The weathered material is the first step towards formation of solid derived from rocks as its parent.

Agents of Gradation

Any natural agency capable of transporting the weathered rock material is known as an agent of change or gradation, viz., running water, groundwater, moving ice, wind and the sea waves. They derive their energy indirectly from the sun and work together with the force of gravity. These active agents carve out landscape features like valleys, residual ridges and hills and continuously modify them. They perform the work of erosion, transportation and deposition of the loose surface material by removing and dumping it in depressions or finally in the sea.

Running Water

By far the most important agency of land sculpture, on face of the earth is the running water concentrated in small channels and gullies to form streams. The slope of a stream channel lessens in its journey to plains. The speed is reduced because of the great amount of material added to it, and is increased as and when the volume of water increases. Initially in its mountain course a stream flows rapidly but may carry little sediments. In course of its passage, it picks up more and more of rock fragments from its sides and from its bottom. The sand, silt and pebbles are

carried within stream water in solution or suspension. The stones from the rocks and boulders are rolled along the bed of the stream. The particles get smoothened and rounded as they strike against each other and against sides and bottom of the river valley. This is known as *erosive work* of the stream. The amount of material that a stream can carry is called its load. The added load of this debris starts depositing in flood plain and in delta region and the sea floor. Thus, a river is engaged in the work of erosion, transportation and deposition.

The erosion and transportation depends upon the energy of a stream. The volume of water and speed of its movement provide energy to it. The running water by itself has little erosive action. The double work of corrosion or degradation of rocks by mechanical means, and corrosion or chemical weathering of the solid rock supply the load or the cutting tools for erosion. The corrosive work is mainly dependent upon the sediment load which a river current drag along with it. The slower corrosive work depends upon volume and composition of water and the nature of rock. The eroded rock material helps the running water in deepening or vertical downcutting into the bed of the channel, lengthening as well as the widening of a river valley. The transporting power of running water increases by 64 times if the speed of water is doubled. If its volume is doubled, this power is also just doubled. Hence, a swift mountain stream can transport much more than a river in plains having a large volume of water but flowing at a slow speed. A stream can carry a much larger load of the fine material than that of coarser type. The distance upto which the eroded material is carried depends upon the size and weight of the fragments.

During floods, the amount of rock debris carried by river is large enough. Hence, huge boulders found stuck up or along the river are moved during seasonal floods. Thus, in a certain part of the year a river is less active, while at other times it is a vigorous agent of erosion and transportation. The Himalayan rivers like the Kosi and the Brahmaputra have not only caused greater destruction during floods in north Bihar and Assam respectively, but brought about greater sufferings by frequent changes in their courses.

A fall in transporting power either by decrease in velocity or the volume of water or by an increase in load of a stream, leads to dropping of the material it carries. Much of the sediments is left deposited at the sides at sheltered places, at its mouth or even in the bed of the river. Nearly one-fourth of it reaches the sea.

Now let us study the action of river on its valley from source to its mouth in relation to the features developed by it. The upper or the mountain course begins at the source of the river in hills or the mountain areas. The river tumbles down the steep slopes and as a result its velocity and transporting power are at its maximum. The vertical downcutting into its own channel gives us deep, narrow and distinctly V-shaped valley. At places where the side rocks are very resistant, the valley becomes very narrow and sides so steep that *gorges* are formed as in the Himalayas where rivers like the Satluj, the Indus and the Brahmaputra have cut their way through the high mountain ranges. In arid areas of little rainfall, the valley sides fail to be widened at all and the river cuts deeper only in its floor. This results in the formation of *canyons* or deepest gorges like that of the Grand Canyon, of river Colorado in the United States of

America—strictly I-shaped extending for 200 km long. Such gorges are also developed in highly porous and permeable rocks like limestone where rain-water seeps into the ground leaving little scope for valley-widening at the top. In areas with heavy rainfall and non-resistant rocks, the weathering and the stream action combine in widening the valley. In this part of the river's course the process of headward erosion also lengthens the valley by cutting back into the source region. Some of the Himalayan rivers like the Satluj and the Kosi have shifted their sources on Tibetan side across the main Himalayas through this process. River Kaveri in South India has also shifted its source further westwards in Western Ghats, likewise.

The formation of *rapids and waterfalls* is a most characteristic feature in upper course of a river. The occurrence of the band of a hard-rock along the path of a river makes it jump over or fall downwards. This leads to the formation of rapids at places where the hard valley bottom offers greater resistance to the erosion than the strips above and below it. Some rapids can be rendered harmless for navigators by blasting. On the other hand, when especially small rivers tumble down almost vertically from a height along its course, these are called the *waterfalls*. A bar of resistant rock lying across a river valley leads to the formation of a waterfall.

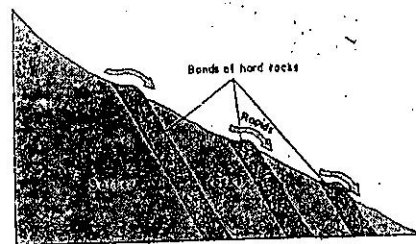


Fig. 9.1 Rapids

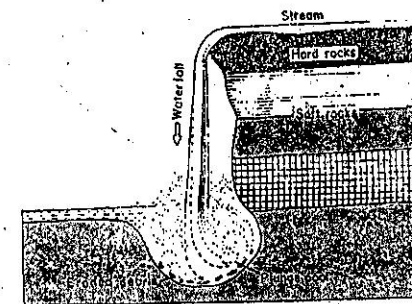


Fig. 9.2 Waterfall

or a series of rapids, as in the case of Niagara Falls of North America (120 metres drop) and Victoria Falls (50 metres) on Zambezi river in South Africa or a plunge down the edge of a plateau like river Zaire of Africa.

In glaciated areas at points where tributary stream joins the main stream, the over-deepening of the main valley leaves the side valley hanging high above the valley of the master stream. A waterfall is noticed at the point where the tributary stream falls down into the main stream.

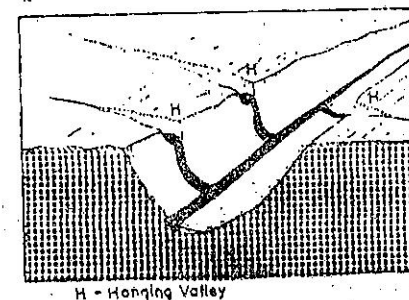


Fig. 9.3 A hanging valley

In our country, Jog or Gersoppa Falls on a tributary of the Kaveri river in Karnataka are seen recording a plunge of 260 metres in a single fall at the edge of Western Ghats. The Dhuandhar Falls in

the marble rocks near Jabalpur are only of 9 metres but are famous on account of their scenery and by volume of water. The river Indravati in Bastar District of Madhya Pradesh falls from over a cliff from a height of 27 metres and Subarnarekha river near Ranchi creates 97 metres high Hundroo Falls in Chota Nagpur plateau.

Usually the great erosive force of the falling water cuts into the softer strata of rock at the base underlying the harder beds. It makes the waterfall retreat slowly upstream by the impact of the erosion at the site of the plunge pool. A gorge starts, forming at the site of this pool because of the river cutting back in this manner. A waterfall is an irregularity in the river's valley floor. The deep defiles, rapids or waterfalls mark the youthful topography in river's upper or torrential course.

The middle or the valley course occurs where the volume of water is much greater because of the preceding enlargement of the catchment area. The slope and velocity has lessened, side or lateral cutting is more active than the vertical cutting and stream

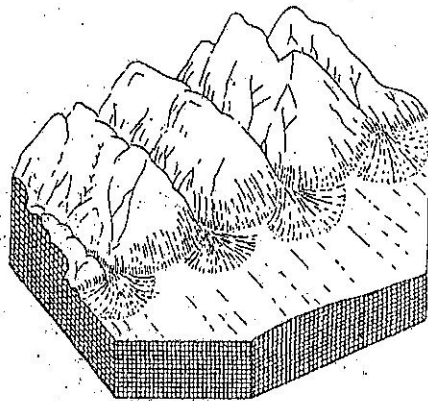


FIG. 9.4 Formation of alluvial fans

wanders in great loops or meanders. Some deposition of the eroded material takes place as around the points where a stream descends from mountains into the plains. The fan-shaped mass of coarser material composed of sand, gravel and boulders is strewn forming an alluvial fan. The merging of such adjoining fans has given rise to Bhabar plain at the foot of the Himalayas in Ganga plain.

To and fro movement of the river channel across its plain results in developing S-shaped *meanders*, common to all rivers of large size. The word 'meander' is derived from the name of a small winding river 'meanderes' in Turkey. The stream flow being slower, the load becoming heavier, it starts winding, first cutting at the one bank and then eroding at the other. The loss of cutting power makes the stream avoid the obstruction created by its own silt load in its path if it cannot remove it easily. This causes a bend in the river when it goes round such an obstruction. The current is always stronger and deeper on outer side of the bend, while sediments are deposited at its inner side where water is less deep and flow is slower. The eroded bank starts retreating, making the bends sharper until loops are formed.

The lower river plain is characterised by an excess deposit of the load on the floor of the channel because of the reduction in its carrying capacity of the slow moving stream. The stream which thus gets divided into a network of channels, forming bars of sand and islands, is known as a *braided stream*.

The main river along with a large number of its tributaries starts depositing a huge load of sediments, it has brought with it. Every year during the floods, a coat of fresh alluvium spreads far and wide along both sides of the river and at confluences of the tributary streams. It

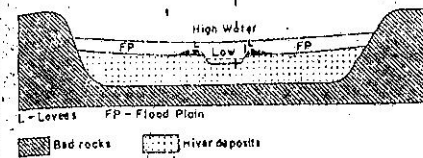


FIG. 9.5 Cross-section of a flood plain

results in the emergence of a wide flood plain in this part of a river's course. A sort of a mound or natural levees consisting of relatively coarse material get building up immediately along each bank of the river. Beyond the levee, fine alluvial mud is scattered layer by layer each year. Both the bed of the river and the levees are raised through accumulation of the deposits. A time comes when the adjoining flood plain is lower than the bed of the river. The levees or sometimes artificially raised embankments fail to contain the pressure of flood waters. These are burst over by the river giving rise to huge destruction by floods. Such has been the cause of disastrous floods in the Huang He river of China, known as China's sorrow for long. The avoidance of obstruction created by the silt deposit which brings the meander into existence also tends to destroy it. This phenomenon is observed in lower as well as in middle course of a river valley. The meanders widen until their two ends meet by the entrance of the loop getting silted up. The meander is cut off from the main stream, when it cuts a straight course through the narrow neck of the loop. The stream has to resume such a course because it is no longer capable of entering the meander through a heavy bankslide of soft alluvium. The meander, now cut off, takes the form of an *ox-bow-shape* lake gradually turning into swamps and disappearing in course of time. Numerous such partially or fully filled ox-

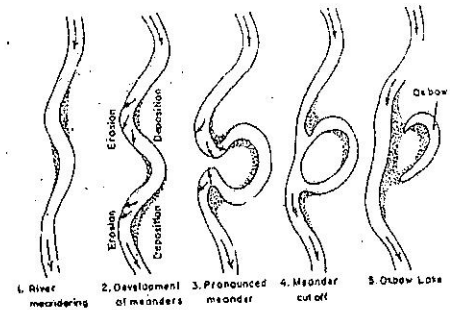


FIG. 9.6 Development of meanders and ox-bow lakes

bow lakes are marked at a short distance from the present course of rivers like Ganga.

Upon entering a lake or a sea, the river deposits all the load at its mouth giving rise to the formation of a *delta*. It is a triangular feature with its apex pointing upstream and is marked as a fan-shaped

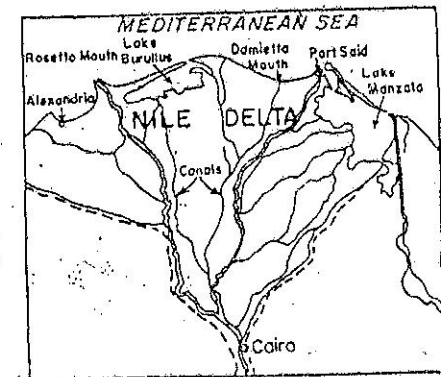


FIG. 9.7 Formation of deltas

area of fine alluvium. The Greek letter (Δ) closely resembles the triangular delta of river Nile. It is rather an extension of the flood plain seawards.

The large supply of fine alluvial material and the absence of strong tides and currents at the river's mouth are two major factors favouring delta formation.

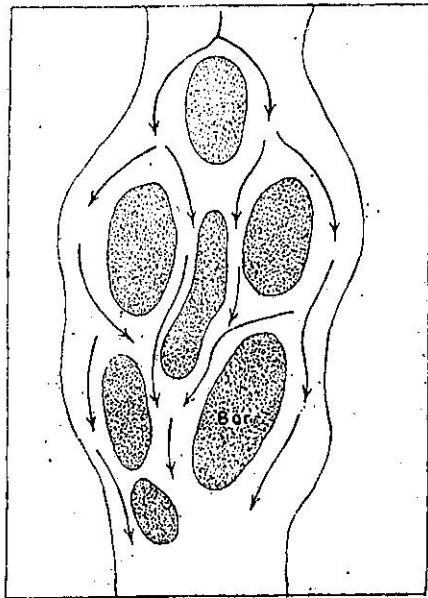


FIG. 9.8 Braided stream

That is why we have the biggest delta of the world at the mouth of Ganga-Brahmaputra rivers, but it is not found at the mouth of river Narmada along west coast of India. The penetration of saline sea-water through the water channels further contributes in coagulation of the sediments settling in or along the streams. The mud deposited along the banks because of slow carrying capacity of water becomes an obstacle and divides the river into numerous branches called *distributaries*. The development of the network of such channels and sub-channels goes on extending the delta area.

The river has no alternative but to discharge its water sluggishly only through these distributaries. With constantly settling sediments, the delta grows vigorously as long as the water channels are not completely choked by silting. Even trees and shrubs grow over the muds rising above water, turning the sea mouth shallower by their deposit. The seawards growth of delta is modified sometimes by the currents, deflecting the mud to one side. The size, shape, and the rate of growth of the delta is variable as it depends upon the interplay of a number of factors. The Ganga-Brahmaputra Delta, 125,000 sq km in area, is one of the biggest deltas of the world. Other well-known deltas are of rivers Nile, Mississippi, Po, Volga and the Yangtze.

Cycle of Erosion

The depositional and erosional features produced and modified through the action of running water are better understood if we note the stage through which a stream passes and develops the valley-forms associated with each stage. It was W.M. Davis, an American Geographer, who suggested that the landforms undergo changes as a result of an interaction of the structure and character of rocks, processes of change and the stage of erosion a given area has reached. According to him these changes follow each other in a definite sequence termed as stages. For this reason he named it as a cycle of development of landforms or the *cycle of erosion*. Most commonly, the stages of youth followed by maturity and old age are considered in explaining the evolution of landforms by different agents of change. In the case of river valley development, the cycle is known as a normal cycle of erosion as its operation is relatively most widespread wherever water is present over the globe.

The initial raised relief is fully reduced at the completion of this cycle and the surface is levelled down by that time.

It is, however, an abstract idea and cycle of erosion is more a theory than a practical proposition. Most of the cycles of erosion do not reach the final stage because of climatic changes or accidental disturbances as a result of earth movements. The course of the cycle gets interrupted by such changes, a mature topography becomes young and the cycle re-starts. In other words, a new cycle starts running within the old.

Development of River Valley

A river has a maximum gradient in its upper reaches, it is less in its middle course and the least in the lower part. In the upper course where its cutting or erosive power is the greatest, it is said to be young. In its middle course is the second mature stage, the erosion and deposition are balanced. In the lower part, the river enters the third stage of the oldness where the

deposition becomes greater than the erosion which practically stops. The topography consisting of the features typical of three parts or stages of a river is said to be youthful, mature and old, respectively. While youthfulness prolongs in the upper course, old age may come earlier in the lower course of a river. The cycle of erosion begins by the action of running water on a land surface recently raised above sea level. Each of its stage mentioned above is identified by a distinctive mechanism of river work and the landscape. The typical set of landforms and the processes characterising each stage achieved in different tracts of a river valley have already been analysed.

In general the diagram of the river's bed from source to its mouth shows a smooth curve known as the *graded profile*. It is flat near the mouth, increasing in steepness towards the head waters. The level of the lake or sea into which the river flows is known as its base level or the grade. It is the level at which a river is

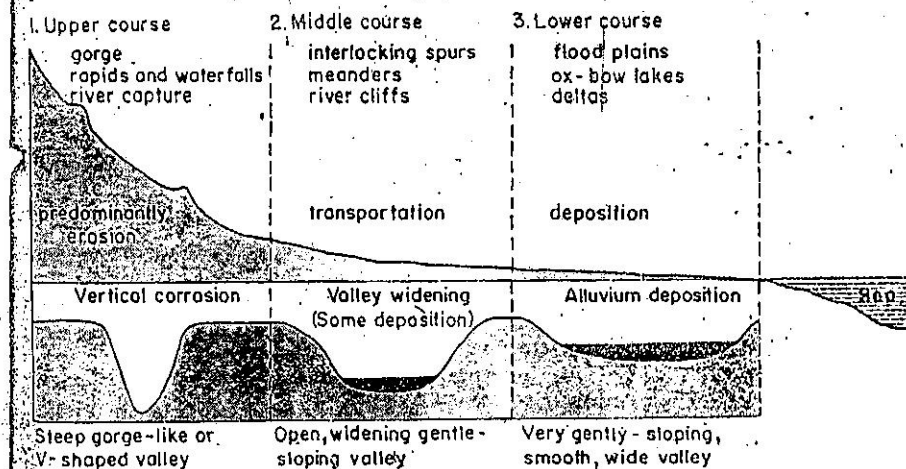


FIG. 9.9 A river valley profile

likely to flow at or near the sea level. It is, in other words, the lowest slope over which a stream can carry its load of sediments. No river can cut its valley much below the base level which is the final goal it has to achieve. An individual stream may, however, have temporary base levels such as a lake on its way or the river to which it is a tributary.

A permanent base level is achieved only when all irregularities in the course of a river are reduced and the topography becomes almost level. This goal is seldom achieved or once achieved it is not fixed for ever. The sea level which is the most permanent of base levels is not stationary for all the time.

Let us see how the ultimate base level or final stage of erosion cycle is not likely to be reached. If the lake where a river ends or sea retreats by an increase in snow deposits over the mountains, the base level subsides. The smooth graded curve breaks in the lower reaches and the river begins once again to erode upstream, since it always works out its new profile backwards. By cutting its bed in the previous deposits, it leaves part of them on both banks in the shape of terraces. The process may take hundreds and even thousands of years but subsidence of the base level, causing the river to cut into its deposits or even into the bedrock, may be repeated many times. If, on the other hand, the entire tract is elevated, the new cycle of erosion begins in upper reaches where gradient has changed. A rise in sea level as a result of decrease in snow deposits over the mountains because of climatic change weakens the erosive power of streams mostly in lower course.

If the movement of the earth's crust or a major climatic change makes old stream young, it is called *rejuvenation*. A stream is rejuvenated when land is elevated near its headwaters or sea level sinks near its

mouth. The stream's ability to erode is renewed and downward cutting begins. This results in the formation of river terraces and meanders get incised between steep sides. There is a slight break in slope and change in the shape of the valley. If rejuvenation does not interrupt the cycle, the sea level rises or land submerges, the young stream becomes an old stream and lowering as well as extending of its basin continues. These changes may bring the completion of the cycle in sight, other things being equal.

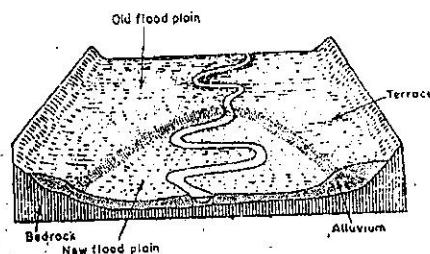


FIG. 9.10 River terraces due to rejuvenation

Drainage Patterns

The riverine topography develops well in fully evolved drainage basin. A main stream or a river with all its tributaries produces a river system or a drainage basin. The higher ground separating the two drainage basins is called the *watershed* or a water divide. The Western Ghats, for instance, serve as a watershed between the streams draining into the Bay of Bengal on the one hand and those draining into the Arabian Sea on the other. The uplands or the mountains through which a river flows describe its catchment area from over which it draws its water. Originally when rivers flow in the direction of the slope or as a consequence of the slope, they are called the *consequent streams*. As soon as

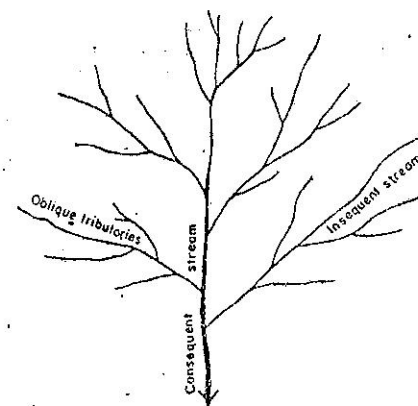
such a river is joined by its tributary, it is called the *subsequent stream*. The subsequent stream is controlled by the underlying rock structure as it flows on weak strata lying near the master stream on its either side. If rocks are composed of homogeneous beds the rivers flowing over them do not have to adjust to differences in rocks. Such rivers are called the *insequent rivers*. All these river systems produce four common drainage patterns: dendritic, parallel, trellis and radial.

The *dendritic pattern* is the pattern of insequent streams and is tree-like. The word *dendron* means tree in Greek language. The main river is like the trunk of a tree and the tributary streams join it like branches of a tree at a small angle. The pattern is enlarged by increasing the number of tributaries in the beginning, simplified by having a few tributaries of large size in the long run.

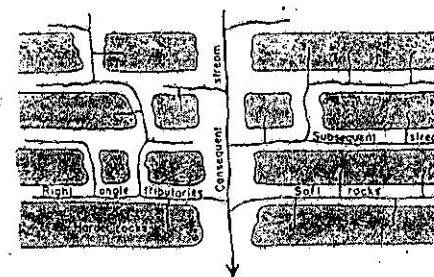
A *parallel pattern* develops on steep slopes with master stream and its tributaries flowing almost parallel to each other for a considerable distance before meeting. A *trellis pattern* develops on a folded structure consisting of resistant anticlinal ridges separated by synclinal valleys. The rock strata is not uniform as in the case with the dendritic pattern. There are long straight river valleys with their tributaries joining almost at right angles, making it look like a rectangular arrangement known as *trellis pattern*.

The *radial pattern* consists of drainage lines radiating from a central part in all directions as on a dome.

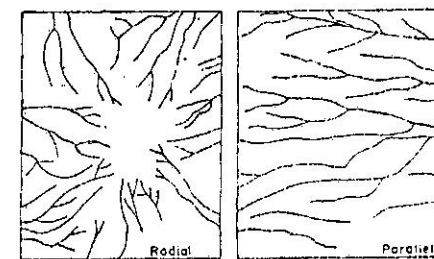
Besides these major drainage patterns, an *internal drainage* is met within deserts where streams merge into the encroaching sands and fail to have their exit into a sea or a lake basin. An *antecedent drainage* is observed in mountains where a continuous downcutting has enabled the rivers to



(a) dendritic



(b) trellis



DRAINAGE PATTERNS

(c) radial

(d) parallel

FIG. 9.11 Drainage patterns

make their way through the mountain ranges rising subsequently along their way.

Moving Ice

Ice, like water moves and leaves behind a distinct landscape. It can be recognised in mountains and in high latitudes which were covered by glaciers long ago.

In regions where temperatures are below freezing-point, precipitation falls as snow. Wherever the rate of snow melting or its evaporation is lower than the rate of snowfall in a year, snow accumulates into great mass of ice. The fresh fluffy snow becomes solid, compact and granular ice when it keeps lying on the ground for sometimes. The pressure and refreezing of moisture converts snow into ice little by little far below zero degree temperature. As the air between the ice particles goes out under overlying pressure, the snow, granular ice becomes truly compact. Lying at the base of fresh snow, ice moves both under pressure and gravity. Such a flowing but slow moving river of solid ice is named as glacier. It was first of all in 1834 that a Swiss named Louis Agassiz proved the movement of ice in a glacier. Glaciers flow out from snow fields which are the large areas covered permanently under snow. These are found in every continent except Australia. Snow fields are always situated above the snowline which is the lowest limit of perpetual snow. While the height of snowline is at sea level in polar regions, it is at over 5,000 metres in equatorial region. Its height also depends upon the volume of precipitation. Thus, on southern slopes of the Himalayas, the height increases from east to west from 4,250 metres to 5,800 metres on account of a progressive decrease in moisture supply. Both because of steep southern slopes of the Himalayas and a gradual decline in

moisture supply northwards, it is found higher as we move northwards towards drier inner parts of the mountain region. The seasonal snowline comes down to lower altitude in the Himalayas in winter season. The conditions favouring the formation of snow fields above the snowline are (i) the gentle slopes from where it cannot easily be swept off by wind or breaks off the slope as an avalanche; and (ii) the hollows or localities sheltered from direct sun.

The moving ice both erodes and deposits the material it transports along its bottom, within it or 'added' upon its surface from the side rocks. The pre-existing topography is fully removed and totally new landforms are created in its place by the moving masses of ice or glaciers.

Glaciers are grouped into four types, viz. continental glaciers, ice caps, piedmont glaciers and the valley glaciers. The present day continental glaciers or huge ice sheets are smaller as compared to such glaciers of the past, once covering large areas of northern Europe, Asia and northern half of North America. Today, these are found in Antarctica and Greenland. The biggest continental ice sheet in Ireland, for example, has an area of 8,450 sq km and thickness of its ice is 1,000 metres. Ice caps are the covers of snow and ice on mountains from which the valley or the mountain glaciers originate. The piedmont glaciers form a continuous ice sheet at the base of mountains as in southern Alaska.

The valley glaciers, also known as Alpine glaciers, are found in higher regions of the Himalayas in our country and on all such high mountain ranges of the world. While the continental ice masses covering thousands of square kilometres and thousands of metres thick

move outward in all directions from their central portions, the valley glaciers move down the mountain slope towards lower regions. There is a great variation in their size. The largest of Indian glaciers occur in Karakoram range, viz., Siachen (72 km), while Gangotri in Uttar Pradesh (Himalayas) is 25.5 km long and many others are as small as 5-10 kilometres in different parts of the range.

The valley glacier consists of a broad reservoir of ice at its mountain head from which a tongue of ice moves down the pre-existing valleys to a warmer climate, where ice disappears by melting. In periods of heavier snowfall year after year, these glaciers have advanced to lower limits and during periods of lighter snowfall, they recede to higher limits. They have generally been advancing before 1858 and are now reported to be receding from their old limits. Much of their ice is getting wasted under the dry climate in the current period. The glaciers are, therefore, a barometer of the trends of climatic changes. A valley glacier is not only a mass of ice but it is loaded with rock material from top to bottom. This material is called a drift, or boulder, or boulder clay, because it is heterogeneous and has boulders mixed with clay. Much of it is unsorted and angular, unlike the founded water-worn stones. Pure ice, like pure water, is least erosive and rock debris supplies efficient erosive tools to the glacial ice scouring, scratching or plucking the rocks around. It is because of them that the rocks worked over by the ice get polished, and there are grooves and striation marks on their faces.

The rate of movement of glaciers varies from an average of 18 metres a day in summer in Greenland to about 3-40 centimetres a day in other areas. The velocity of moving ice increases with steepness of slope of the area upon which

it flows and thickness of glacial ice. For this reason, it goes on decreasing from middle to the sides owing to lesser depth of ice and friction against the valley walls and the bottom floor. Heavy load of debris along its margins also retards the movement.

As a result of an unequal movement of ice within a glacier, the top with least amount of friction moves much faster than the base. The cracks marked on the glacier because of the splitting up of ice as a result of its unequal movement are known as crevasses. As its marginal parts lag behind those of the centre, short and shallow crevasses are formed running from margins to the middle across the glacier. Many more crevasses are formed across the entire glacier where the slope of its bed, i.e., the floor of the valley becomes suddenly steeper. Here the ice cannot keep pace with its faster movement and the glacier breaks up into separate blocks on such steeper slopes. Downwards where the gradient is gentler again, crevasses gradually join, the blocks of ice unite, and the glacier becomes smoother. The crevasses in the direction of flow usually develop when a glacier

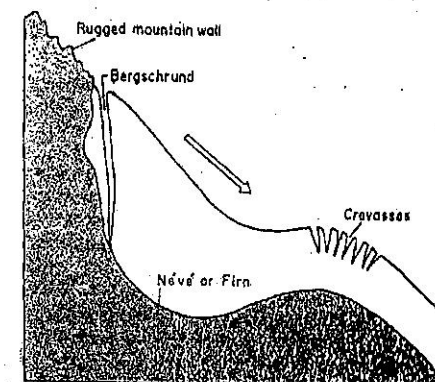


FIG. 9.12 Characteristic features of the glaciated highlands

becomes wide on leaving a narrow valley. The crevasses on the glacier are dangerous to the travellers when hidden by fresh snow since many of them are from one to two metres wide and may be 50 to 200 metres deep.

A glacier armed with sand, gravel and pieces of rocks has a powerful abrasive effect, like the effect of a sand-paper on furniture. Although glacial erosion affects only a small part of the earth's surface and is not continuous, the landforms associated with it like U-shaped valley trough, hanging valley, cirques or corries and sheep rocks are typical of glaciated regions.

U-shaped Valley

Mountain glaciers cannot dig a new valley but deepen, straighten as well as widen the pre-existing valley by eliminating irregularities and projecting spurs during its passage. Such a trough has steep sides, wider floor and truncated in place of interlocking spurs. This enables us to see over a longer distance in a glaciated valley. The original V-shaped valley becoming narrower towards its head is turned into a U-shaped trough in this

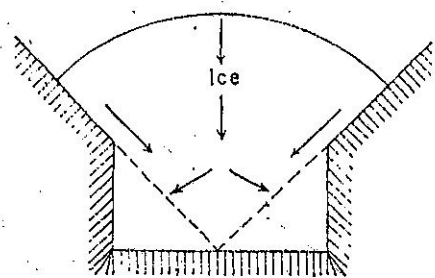


FIG. 9.13 Change from V-shaped valley to U-shaped valley.

way. The formation of hanging valleys is another characteristic of such regions. The smaller glaciers filling the tributary valleys

do not erode as deep as the big ones filling the main valley.

After melting of the glacier, the tributary valley, called the *hanging valley*, is found at a height from the main valley floor. This is visible only after the glacier melts standing as clues to the erosive action of the glacier.

Cirque or Corrie Basin

It is a common feature found at the head of a glaciated valley. It is a large circular or amphitheatre-like or an armchair-type of hollow cut into the mountain ridge. It is open at one end, has a flat bottom and very steep rocky slopes on three sides. It is separated from the main valley down its open end by a slightly higher ground. Where several cirques erode cutting a mountain back towards a common height from different sides, a horn-shaped *pyramidal peak* is formed. The Matterhorn Peak of Swiss Alps is the famous example of it. The frost weathering and the plucking action of ice starts the formation of a *cirque*. Gradually, it widens and becomes a collecting ground for snow from

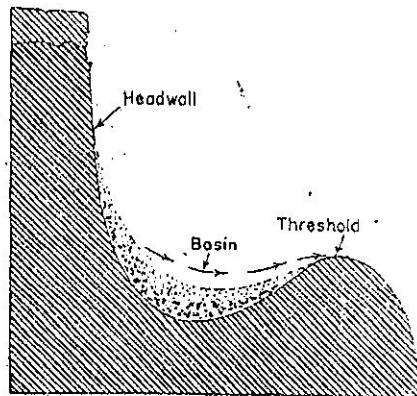


FIG. 9.14 A cirque

the steep mountain walls on its sides where it cannot rest. A mountain lake called *tarn* is observed at the bottom floor of the cirque basin after melting of the glacial ice. It is the result of a long-standing grinding action of ice behind the higher ground of the exit.

Sheep Rocks (Roche Moutonnées)

A glacier does not avoid hard outcrops like cliffs falling along its path. It rides or flows over them in a manner that the slope of the obstacle from the side the ice moved becomes gentler, while the other side where the ice flowed down is left rougher and steeper. These knolls having a rag and the tail look like sheep from a distance.

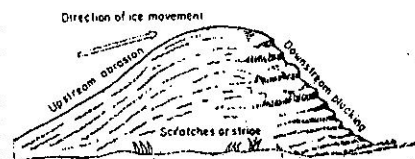


FIG. 9.15 Roche Moutonnées

Glaciated Lakes

Long ribbon of finger-shaped lakes got excavated into the flow of glacial troughs as a result of ice erosion. The great lakes of North America have been formed by a similar deepening and damming. At some time in the life history of a glacier, it melts leaving sediments at the front of ice where melting occurs. At such sites, depositional landforms like *moraines* are observed. Moraines consist of the heterogeneous rock material of unsorted nature. It is a mixture of fine sediments called *glacier flour*, angular stones and boulders of different sizes and shapes. The pile of such stones and boulders is known as *glacial till*. This material dropped at the end of a valley

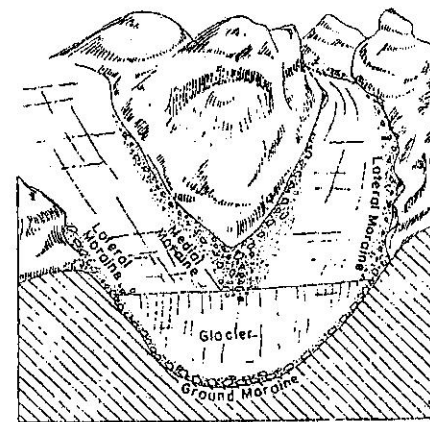


FIG. 9.16 Moraines

glacier is in the form of ridge called the *terminal moraine*. Each time a glacier retreats, a fresh terminal moraine is left at a short distance behind the first one. The material deposited at either of its sides is known as *lateral moraine*. When two glaciers join, their lateral moraines also join near their confluence and are called *medial moraines*. Many alpine pastures in the Himalayas like Margs of Kashmir occupy the sites morainic deposits of old river valleys. The excessive load that cannot be carried forward by a glacier is deposited on its own bed or at the base and appears as what is known as *ground*

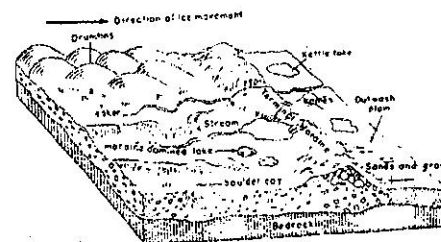


FIG. 9.17 Glacial deposits

moraine. Glacial deposition produces a variety of forms as a result of not only glacial but fluvio-glacial action subsequent to the melting of ice in the lower parts of glaciated region. If a ground moraine is deposited on a level surface, roughly irregular knobby-type of low hills arise. Deep hollows or kettle holes are left, if the deposit is shallow on this surface. If, on the other hand, ground moraine is deposited in a rough topography, depressions are filled by it and the tops of hills smoothened or rounded. These low hills always found in clusters are called *drumlins*. If melt-water of the glacial stream coming out of the ice tunnel under the snout of the glacier brings out the sediments to some distance, some sorting occurs. These snowmelt deposits make features like an *alluvial fan*, and delta-like *outwash plain* of sand and gravel. It is so named because the material has been washed out of the morainic deposit. Since it spreads over the valley bottom from side to side, it is also given the funny name of 'valley trains'. Long winding and very low ridges of sand and gravel looking like natural embankments marking the sites of sub-glacial stream channels is another noticeable feature known as *Eskers*.

Work of Wind

The work of wind as an agent of gradation is not as widespread as that of water. It is effective in desert regions of the world where rainfall is scanty and soil particles are loose in the absence of any moisture and vegetation. The work of wind is greatly helped by the process of mechanical weathering active in such areas. A plenty of loose disintegrated rock material is provided for the wind to pick up. The wind has a great scope to work with it by blowing over large areas free of any obstacles.

The wind, by itself, just like water and ice, has little erosive effect on rocks. The loose rock material carried by wind acts as its tools in wearing them down. This work of wind is limited to heights close to the ground, as it is unable to carry the sand particles high up in the air. Wind action also depends on the size of grains carried above or moved along the ground. The speed of the wind and the length of time it continues to blow also influences its erosive work. Firstly, the sand grains wear away the rock by abrasion, polishing or scouring the rock surface just like a sandblasting machine. Secondly, the loose surface material is blown away by wind from land through a process known as *deflation*. Polished rock surfaces and boulders having big cavities in them are often observed in deserts facing the direction from which the wind blows. The maximum erosion of an upstanding mass of rock occurs slightly above its ground level, where friction close to the ground is absent and sand content in air is yet high. The intensity of cutting into the rock decreases, both upwards as well as downwards from this level of maximum erosion by wind. The isolated granitic rock masses near Jodhpur (Rajasthan) are found similarly undercut giving them a

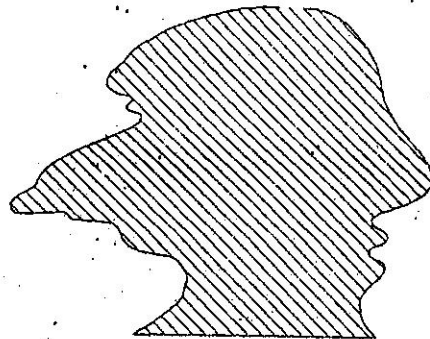


FIG. 9.18 Mushroom rock

characteristic mushroom form. The harder cap of these *mushroom rocks* based on loose rock survives and giving it such a fantastic shape. These rocks and even medium sized pebbles are found pitted in the direction from which the sand-laden wind comes producing numerous edges. At times and at places, wind removes the sediments down to the water table as a result of continuous deflation. This gives rise to a fertile oasis.

When the velocity of the wind decreases, it starts dropping its load. Some of the important depositional features due to wind action are the sand dunes and loess deposits.

Wind-borne loess consists of such a fine dust particles and are transported over great distances, sometimes quite beyond the desert regions. As the fine grains have the property of clinging together, their deposition gives distinct landforms. The material has no horizontal stratification like other sedimentary rocks. Since it is deposited in areas of low-rainfall where ground has grasses to bind the particles of dust, the loess stands without being removed further by the wind. The deposit although soft, is at the same time resistant to erosion and streams have cut down deep valleys into it with almost vertical walls of loess standing on their sides. It is striking, on the other hand, that it crumbles to dust if pressed between fingers. It blankets both the elevations and depressions alike over the ground surface. The loessic soils are porous and usually very fertile. In wet they form a sticky mud and in dry season it is very dusty. The loess of North China has a maximum thickness of several hundred metres. It is yellowish or buff in colour. It has been brought mostly from the Gobi Desert of Central Asia over many years.

Sand dune is a mound, a hill or a ridge of sand with a crest or a definite summit.

These are formed at places, where there is a source of sand, a wind strong enough to move it, and some obstacle to break the force of the wind enabling the material to drop. The obstacle may be a bush, a rise in ground, a boulder, a fence, a house or even the skeleton of a dead camel.

A typical dune has a long and gentle windward slope and a much steeper leeward slope. They vary in size from a few metres to about 150 metres in height. In some deserts, they have been noticed as high as 300 metres. Besides deserts, sand dunes are also formed in flood plains of rivers and beaches along sea coasts and lake shores wherever loose sand is available.

Sand dunes, if not fixed by vegetation have a tendency to migrate slowly in the direction of the wind by the shifting of sand from the windward to the leeward slope. The rate of migration varies between 5 metres to 30 metres a year. During the course of migration, they sometimes bury up the woods, pastures and villages on the way. With the passage of time after the dunes have drifted further on, the buried dead woods and village ruins reappear. Encroachments from local shifting of dune-sands have also been noted in and around Rajasthan desert in dry periods. The planting of fast-growing and deep-rooted shrubs and trees on the windward

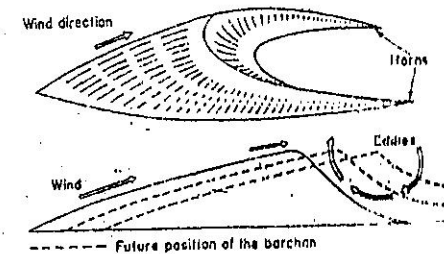


FIG. 9.19 Barchans

slope holds the sand in a place and prevents further migration of the dune.

Barkhan is the typical dune with a crescent-shaped front, possessing two horns or wings towards the leeward slope and a convex windward side. It is a Turkish word meaning a sandhill in Kirghiz Steppes. As the extremities of this dune move more rapidly than the middle portion, it gives it such a characteristic shape. A constant wind direction and a limited supply of sand are two essential conditions for the formation of Barkhan. Sometimes it attains a height of as much as 30 metres. They also migrate like an ordinary sand dune.

Seif or Longitudinal sand dunes are long narrow ridges of sand, lying parallel to the direction of parallel winds and running often to great distances. *Seif* is an Arabic word meaning *sword* ascribed to the sharp and narrow nature of the sand ridge. The dominant winds blow straight along the corridor between the line of these dunes so that they are swept clear of sand. If a cross wind blows and persists for sometime, one of the horns of Barkhan will be elongated converting it into seif-type of sand dune.

Sea Waves

If we look on the hilly shore along the Western Ghats in India, we can realise the force of the sea waves in breaking the rocks. The sea performs the work of erosion and deposition through sea waves, aided by currents, tides and storms in coastal areas.

The erosive work of the sea depends upon the size and strength of waves, seaward slope and height of the shore between low and high tides, the composition of rocks and the depth of water. When the wave breaks along the sea shore rocks, it develops a considerable

force. It has been estimated that such surf waves can exert pressures from 3,000 to 30,000 kilograms per sq metre. The air contained in the cracks in rocks is violently compressed as a wave advances towards the coast. This is followed by an expansion of the air as the wave retreats. The sudden expansion of the air has an explosive effect resulting in a widening of the cracks and ultimately breaking down of the rocks.

Sea waves, like glaciers and the wind are more effective in breaking down hard rocks when they are armed with their cutting tools, viz., loose rock fragments.

Like the debris of the glaciers, the rock fragments being carried by the sea waves are themselves worn down by striking against the coast, or among themselves.

Finally, erosion also takes place as a result of the solvent and chemical action of sea waves, but it becomes important only where the soluble rocks such as limestone and chalk are under attack.

Sea-cliffs: When the coast facing the sea has a scarp face, it is known as a sea-cliff. To start with, the wave wears away a groove in the rock at sea level called a notch along such a coast. This notch

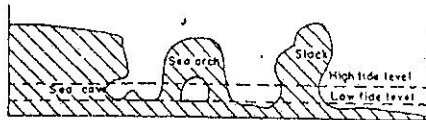
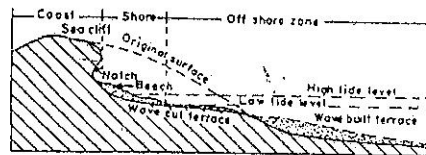


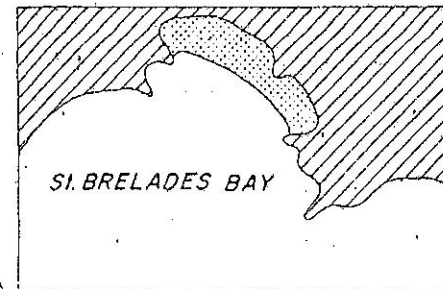
FIG. 9.20 Features due to erosion by sea waves.

gradually widens to undermining the overhanging rock until it slides or falls into sea. When the waves constantly beat against the sea-cliffs, they start receding and land is gradually worn back by the grinding action of the tossing water armed with rock fragments. In India, examples of sea-cliffs, standing like a vertical wall or receding are found on the western coast.

Sea Caves, Stacks and Arches

Waves erode weak rocks faster than the resistant ones. Where rocks are traversed by joints, faults or bands of weak rocks, the differential erosion by waves leads to the formation of sea caves. Caves generally occur when the overhanging rock is strong enough to stand without much support from below.

When sea waves working from opposite



BAY-HEAD BEACH IN S.W. JERSEY

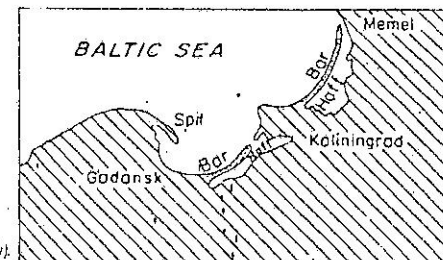


FIG. 9.21 Features due to deposition by sea waves.

directions are able to cut through the caves, a sea arch, or a natural bridge is the result. The portion left standing on a subsequent collapse of a sea arch is called a stack.

The products of wave erosion coupled with the sediments emptied into the sea are redeposited by waves and currents. The marine deposits along the shore modify the coastline through the formation of marine features such as beaches, spits and bars.

Beach gathers the temporary deposit of sand, gravel and pebbles on the shore between the low-tide level and the coastline. The beach grows in size during periods of less active wave attack but may be completely destroyed in a storm by the waves.

Spit is a ridge or embankment of sediments deposited by the waves and attached to the land at one end and projecting in the open sea at the other. It is formed when the waves deposit the rock-waste tangentially to the headland. A *Bar* is an embankment of sand and gravel built on the sea floor by the action of waves and currents. Generally, a bar extends between the two adjoining headlands, or it runs roughly parallel to the shoreline. Headlands are generally formed in resistant rocks, whereas bays are common in non-resistant rocks. It may or may not be tied at both ends to land. The sea-water enclosed between the coast and the bar becomes a partially enclosed lake known as a *lagoon* lake. A lagoon generally maintains connection with the open sea through a narrow gap between the bar and the headlands. The Chilka and the Pulicat lakes along the East Coast and Vembanad on the Kerala coast in the west, are examples of lagoons in India.

Coast and Coastlines

The boundary between the coast and the

shore is known as the coastline, which marks the seaward limit of the coast. The outline of the coast may be modified by sea waves. The occurrence of alternating bays and headlands along a coast may be due to rocks of unequal resistance to sea erosion. By wave action, the more resistant rocks like chalk and limestone give rise to headlands in the form of steep cliffs,

whereas the less resistant rocks like sand and clay form the bays. Coastlines are broadly grouped under two classes, viz., coastlines of submergence and coastlines of emergence.

A *submerged coastline* is produced either by subsidence of land or by a rise in the level of the sea. The important types of these coastlines are Fiord, Ria, Dalmatian

and drowned lowlands.

The *fiord coasts* have been the result of partial submergence of a glaciated area of high relief. These coasts have long and narrow inlets with very steep sides. The fiord mouths are often dotted with small hilly islands which were once the outlying hills. The word fiord, (*fjord*) is of Norwegian origin. The coasts of Norway provide typical examples of this type of coast.

The *ria coasts* are formed by the partial submergence of highlands unaffected by glacial erosion. The sides of the inlets in these coasts have gentle slopes and develop V-shaped profiles. They become uniformly deeper towards the sea and there are generally no islands along the mouths of the rias. The coast of south-west Ireland is a typical example of a ria type of coast.

The *Dalmatian coasts* are developed because of the submergence of mountain ridges which run parallel to the sea coast. Therefore, there is a series of fold mountain ranges with alternating crests and troughs running parallel to the coast.

The Dalmatian coast of Yugoslavia is a typical example of this type from which it derives its name.

A *drowned lowland coast* is low and free from indentations, as it is formed by the submergence of a lowlying area. It is characterised by a series of bars running parallel to the coast, enclosing lagoons. The Baltic coast of German Democratic Republic is an example of this type of coast.

The coastlines of emergence are formed either by an uplift of the land or by the lowering of the level of the sea. This type of coast has bars, spits, lagoons, salt marshes, beaches, sea-cliffs and arches. The east coast of India, especially its south-eastern part, appears to be a coast of emergence. The coast has, however, been invaded by the sea a number of times during the past. The west coast of India, on the other hand, is both emergent and submergent. The northern portion of the coast is submerged as a result of faulting and the southern portion, that is, the Kerala coast is an example of an emergent coast.

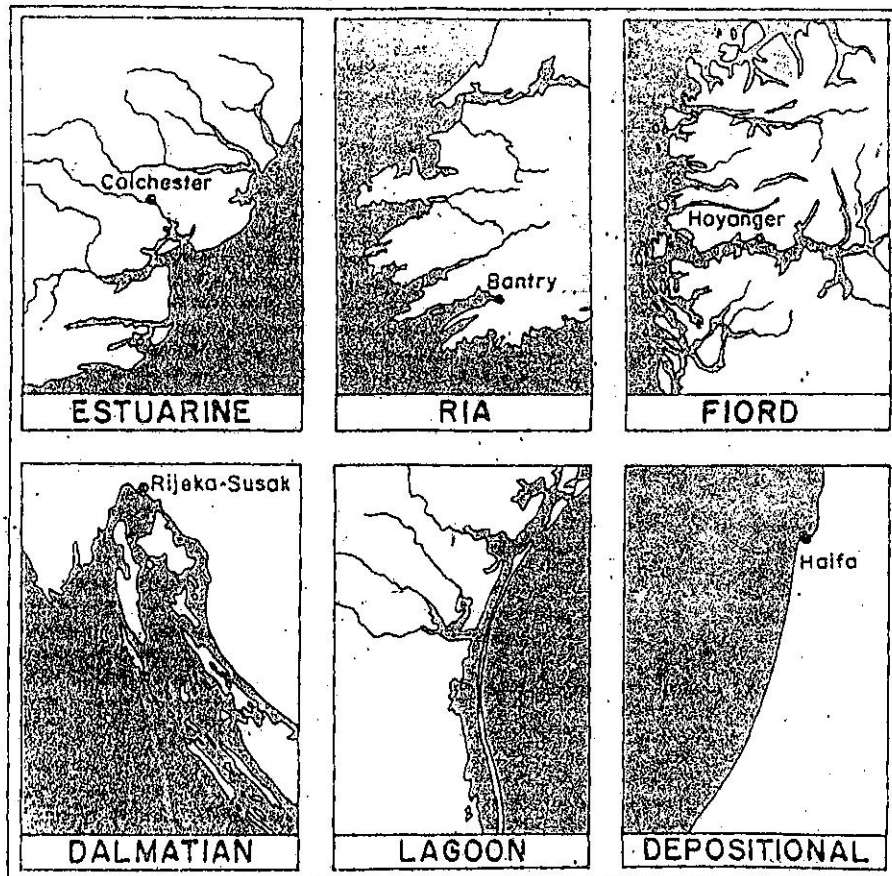


FIG. 9.22 Types of coasts

EXERCISES

Review Questions

1. Answer the following questions :
 - (i) Define gradation.
 - (ii) What is snowline? What factors are responsible for its variation?
2. Distinguish between the following :
 - (i) Erosion and Weathering
 - (ii) Meander and the Ox-bow Lake
 - (iii) Spit and the Bar
 - (iv) Degradation and Aggradation
 - (v) Fiord and the Ria

3. Compare and contrast an I-shaped valley, an U-shaped valley, and a V-shaped valley.
4. What is mushroom rock? How is it formed?
5. What different processes are included in denudation?
6. Discuss in what different ways weathering takes place?
7. How mechanical weathering takes place in cold and hot lands?
8. List out factors which affect (a) energy of a stream, and (b) determine stream's carrying capacity.
9. In what different ways does a river transport its load?
10. How winds abrade and deflate? What are the results?
11. What is meant by differential marine erosion?
12. What are the effects of rejuvenation?
13. How waterfalls are caused? Why a gorge appears along the base of a waterfall?
14. Give a single term for each of the following.
 - (i) The processes that tend to bring the surface of land to a common level.
 - (ii) A stream that gets divided into a network of interconnected channels.
 - (iii) Raised banks or natural embankments built up of coarse deposits along the river channel.
 - (iv) Winding sections or loops of a stream.
 - (v) A higher ground separating two adjoining drainage basins.
 - (vi) A drainage pattern looking like the trunk and branches of a tree.
 - (vii) Chemical action of water with a mineral.
 - (viii) Fragments of rock with which wind, glacier and the river erode.
15. What do we mean by the following expressions :
Outwash plain, Cirque, Esker, Drumlin, Moraine, Loess, Sand dune, Distributaries, Hanging valley, Tarn, Trellis.
16. How would you relate the cirque with the horn peak?
17. Draw a list of landforms in the blank columns against each.

Agents of Gradation	Erosional Features	Depositional Features
Landforms due to running water.		
Landforms due to moving ice.		
Landforms due to wind.		
Landforms due to wave action.		

18. Explain systematically the work of river as an agent of gradation at each of the three stages of its course.
19. Explain how moving ice removes the pre-existing topography and creates entirely new landscape in its place. Briefly describe the landforms associated with glaciated topography.

Finding Out

Find out all that you can about the work of weathering and erosion in your own region and relate it to the explanations given in this chapter.

Cartographic Work

Study the locational information given throughout the chapter with reference to map.

Try to locate at least one landform of each category on top sheets with the help of conventional symbols used.

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UNIT III

The Atmosphere

CHAPTER 10

Composition and Structure of the Atmosphere

THE VAST expanse of air which envelopes the earth all round is called the atmosphere. It contains life-giving gases like oxygen for man and animal, and carbon dioxide for plants. It acts like a greenhouse by trapping the heat. Like the glass in a greenhouse, it allows short wave radiation to enter it and reach the earth's surface. But it is nearly opaque to long wave terrestrial radiation and thus keeps the earth's average temperature 35°C warmer than it would otherwise be. It protects the earth from the harmful radiation from the sun. It also serves as a storehouse for water vapour which leads to precipitation fairly distributed over land and sea. In the modern age, the atmosphere serves as the medium for fast air transport. The presence of air and water on the earth make it a unique planet in the solar system.

The atmosphere extends to thousands of kilometers. But it has no clear-cut upper limit and it gradually merges with the outer space. In the highest levels gases are extremely rarefied.

Composition

The atmosphere is a mixture of many discrete gases, in which varying quantities of tiny solid particles are suspended. Pure dry air constitutes mainly of nitrogen (78) per cent and oxygen (21) per cent which together make up 99 per cent of the air by

volume. Their proportion remains almost constant within lower layer of the atmosphere close to earth. Remaining one per cent is accounted for by gases like argon (0.93 per cent) carbon dioxide (0.03 per cent) hydrogen, helium and ozone. Besides water vapour, dust particles, smoke, salts and other impurities are also present in the air, in varying quantities. As a result, the composition of air is never constant. It varies from time to time and place to place. However, if these variable elements are removed from the atmosphere its make-up would be fairly constant all over the earth, at least in the lower atmosphere.

Of the many constituents, carbon

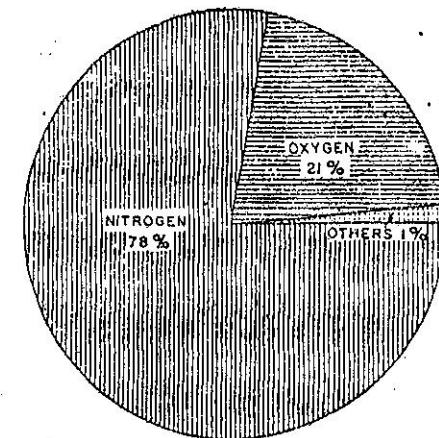


FIG. 10.1 Composition of the air

dioxide, dust particles, water vapour and ozone, are of great importance for the earth's climatic conditions.

Water Vapour

Water vapour is one of the most variable gases in our atmosphere. In the warm and wet tropics, it may account for four per cent of the air by volume, while in the dry and cold areas of deserts and polar regions, it may be even less than one per cent of the air. The amount of water vapour decreases with altitude. Hence, half the water vapour in the air lies below an altitude of about 2,000 metres. It also decreases from the equator towards the poles.

Water vapour absorbs parts of the insolation from the sun and thus reduces its amount reaching the earth's surface. It also preserves the earth's radiated heat. It thus acts like a blanket allowing the earth neither to become too cold nor too hot. Further, water is the only substance that can exist in all the three states—solid, liquid and gaseous at the temperatures normally existing on the earth. When water changes from one state to another, it absorbs or releases heat (termed as latent heat). Water vapour absorbs heat during the process of evaporation. Winds transport latent heat along with water vapour from one place to another, where this heat may be released through condensation and precipitation. The amount of energy released by water molecules (latent heat of condensation) during condensation and precipitation is equivalent to that which was absorbed during evaporation. The released energy plays an important role in producing violent weather like tropical cyclones and thunderstorms. Conditions of stability and instability in the air are greatly influenced by the role of water vapour.

Dust Particles

The movements of the atmosphere are

sufficient to keep a large quantity of the solid particles suspended within it. They may originate from different sources and include: sea salts, fine soil, smoke-soot, ash, pollen, dust and disintegrated particles of meteors. Dust particles are mostly concentrated in the lower layers. However, convectional air currents may transport them to great heights. The amount of dust particles is more in subtropical and temperate areas because of dry and windy conditions than in the equatorial and polar regions. These dust particles are significant from meteorological standpoint. Many of them act as hygroscopic nuclei around which water vapour condenses to produce clouds. They also intercept and reflect insolation. Dust in the air produces marvellous optical phenomenon of red and orange hues in the sky at the sunrise and the sunset. Besides, dense haze and smog (smoke+fog) are also caused due to the presence of dust particles.

Other Gases

Carbon dioxide constitutes only 0.03 per cent of the volume of the air. Even so it is very important meteorologically because it is transparent to the incoming solar radiation but opaque to outgoing terrestrial radiation. It absorbs a part of terrestrial radiation and subsequently reradiates part of it towards the surface. Thus, it keeps the air near the ground warmer and along with water vapour is largely responsible for the greenhouse effect of the atmosphere. Unlike other gases that are constant in volume, the carbon dioxide content of the atmosphere has been rising in the past few decades mainly because of increase in the burning of fossil fuels. This has caused increase in the air temperature also.

Another important component of the atmosphere is ozone. It acts as a filter and

absorbs ultra-violet radiation from the sun. There is very little of this gas in the atmosphere and its distribution is also not uniform. It is concentrated mainly between 10 to 50 kilometres above the earth's surface.

Of the inert gases of the atmosphere, argon is the most predominant gas by volume. Others are neon, helium, krypton and xenon. However, these have little or no importance in affecting weather phenomena.

Structure

The atmosphere consists of almost concentric layers of air with varying density and temperature. Density is highest on the earth's surface and goes on rapidly decreasing upwards. It can broadly be divided into four layers—the troposphere, the stratosphere, the mesosphere, and the thermosphere.

The troposphere is the lowest layer of the atmosphere. It thus lies closest to the

earth's surface. It extends roughly to a height of eight kilometres near the poles and about 18 kilometres at the equator. Thickness of the troposphere at the equator is the greatest because heat is transported to great heights by strong convectional currents. Temperature decreases with height in this layer, roughly at the rate of 1°C for 165 metres of ascent. This is known as *normal lapse rate*. This layer contains dust particles and over 90 per cent of the earth's water vapour. All vital atmospheric processes leading to various climatic and weather conditions take place in this layer. Hence, it is considered to be the most significant layer. However, aviators of jet aeroplanes often avoid this layer due to the presence of bumpy air pockets and fly above it.

Beyond the troposphere lies, the stratosphere. The zone separating the two layers, is known as the *tropopause*. Temperature ceases to fall with the increase in height at this level. The air temperature at the tropopause is about -80°C over the equator and about -45°C over the poles. It is apparently a paradox that the lowest temperature in the atmosphere is vertically overhead the equator rather than over the poles. The stratosphere extends upto a height of 50 kilometres. In the lower part of this layer, i.e., upto a height of 20 kilometres, temperature remains constant. Afterwards, it gradually increases upto a height of 50 kilometres because of the presence of ozone layer which absorbs the sun's ultra-violet rays. Clouds are almost absent and there is very little dust or water vapour. The air movements are almost horizontal.

Over the stratosphere, there exists the third layer known as the *mesosphere*. It extends upto a height of 80 kilometres. Temperature decreases with height again and reaches upto -100°C at the height of 80 kilometres. The fourth layer *thermosphere*

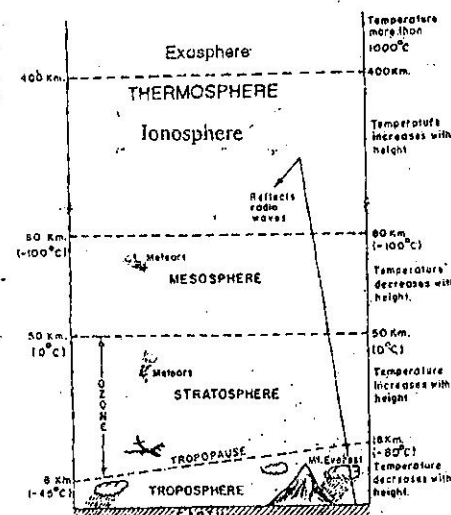


FIG. 10.2 Structure of the atmosphere

is located above the mesosphere. In its lower part, there is an electrically charged layer called the ionosphere. Radio waves transmitted from the earth are reflected back to the earth by this layer. Temperature again starts increasing with

height because of radiation from the sun. The upper part of the thermosphere is called the exosphere. Here the atmospheric gases are very thin. This part is extremely rarefied and gradually merges with the outer space.

EXERCISES

Review Questions

1. Answer the following questions :

- (i) What are the major constituents of pure dry air?
- (ii) What is the significance of dust particles in the atmosphere?
- (iii) How is it that the lowest temperatures at the tropopause are vertically over the equator rather than over the poles?
- (iv) If the temperature at sea level were 25°C, under average conditions what would the air temperature be at a height of 2 kilometres?

2. Write notes on :

- (i) The ionosphere, and (ii) Significance of atmosphere to man.

3. Describe the structure of the atmosphere stating different characteristics of each of its layers.

4. Give a single term for each of the following :

- (i) The zone which separates the troposphere from the stratosphere.
- (ii) The layer of the atmosphere where conditions are ideal for flying.
- (iii) The part of the atmosphere which reflects the radio waves back to the earth's surface.
- (iv) The vast expanse of air which envelopes the earth all around.
- (v) The atmospheric layer lying between stratosphere and thermosphere.
- (vi) The uppermost layer of the atmosphere.

Finding Out

5. Find out what methods and tools are available to gather information regarding the atmosphere.

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CHAPTER II

Insolation and Temperature

THE sun is continuously radiating heat energy into space, which is known as solar radiation. Only a minute percentage of solar radiation—one in two billion parts is intercepted by the earth because of its small size and great distance from the sun. Yet, this small proportion of solar radiation reaching the earth is of great importance. Being the only major source of energy on the earth, it controls many of the physical and all

biological phenomena of the earth.

Insolation

Insolation is the incoming solar radiation. It is received in the form of short waves. The earth's surface receives this radiant energy at the rate of two calories per square centimetre per minute.

Of the total radiant solar energy that strikes the outer surface of the atmosphere, only half (approximately 51 per cent) is

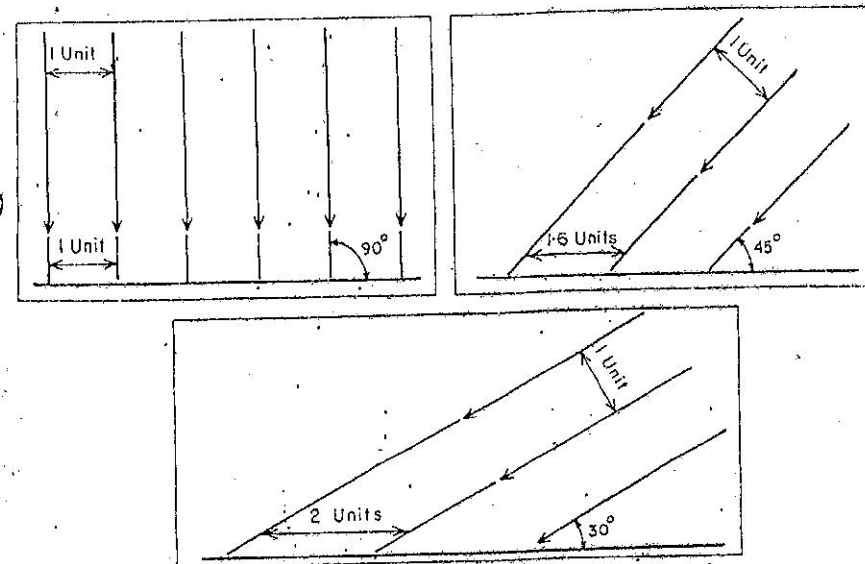


FIG.11.1 Inclination of the sun's rays

able to reach the earth's surface directly or indirectly (scattered) and is absorbed. The rest is lost through scattering (by

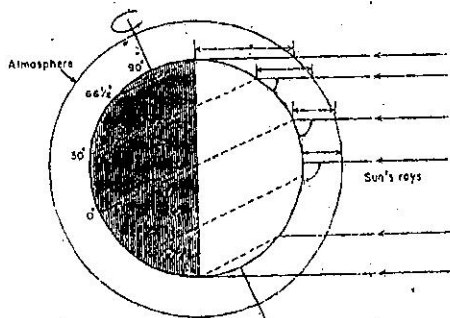


FIG. 11.2 The angle of the sun's rays and the amount of traverse through the atmosphere

gas molecules), reflection (by clouds) and absorption (largely by water vapour) passing through the atmosphere.

The amount of insolation reaching the earth's surface and its effectiveness per unit area depend upon (i) the angle of incidence or the inclination of the sun's rays; (ii) the duration of sunshine or the length of the day; and (iii) transparency of the atmosphere.

Change in the angle of incidence of the sun's rays cause variations in the amount of solar energy reaching the earth's surface in two ways. First, when the sun is almost overhead, its rays are nearly vertical over the surface and are more concentrated. Hence, the intensity of insolation is more. If the angle of incidence is low, rays are oblique. Therefore, spread out is more and intensity of insolation is less. Second, the sun's rays striking the earth at a low angle traverse more of the atmosphere than rays striking at a high angle. Longer the path, greater the amount of scattering, reflection

reduces the intensity of insolation at the surface.

The length of daylight varies with season and with latitude, which determines the amount of heat received by the earth's surface. In fact, the angle of incidence and the length of daylight together control the distribution of insolation on the earth's surface (See Appendix I).

The amount of solar radiation reaching the earth's surface also depends on the transparency of the atmosphere. The amount of cloud cover and its thickness, dust, and water vapour which determine the transparency of the atmosphere affect the reflection, absorption and transmission of solar radiation.

The total annual insolation is maximum within the tropics, beyond which it gradually decreases towards the poles. Along the parallels of 45° latitude, it is only about 75 per cent of that at the equator. It is reduced to 50 per cent along the Arctic and the Antarctic Circles and only about 40 per cent at the poles.

Heating and Cooling of the Atmosphere

Air, like all other substances may be heated in three ways: radiation, conduction and convection.

Radiation

Radiation is direct heating of a body or an object by the transmission of heat waves. This is the only mechanism in which heat can travel through the relative emptiness of space. Hence, the vast amount of energy coming to and leaving the earth are in this form.

The amount and nature of radiation are governed by certain basic laws such as: (a) All objects, whatever may be their temperature, emit radiant energy. As such, not only hot objects like the sun but the earth including its ice-caps emit energy

continuously. (b) However, hotter objects radiate more energy per unit area than the colder objects. Hence, the sun having a surface temperature of 6,000°C, emits hundreds of thousands of times more energy than the earth, which has an average surface temperature of 15°C. (c) Temperature of an object also determines the wave length of radiation. Hotter the object, shorter the wave length of radiation. Radiation from the sun is in the form of short waves. Radiation from the earth is called *terrestrial radiation* and it is in the form of long waves. (d) Objects that are good absorbers of radiation are also good emitters. The earth's surface is a good absorber of the insolation: It is also a good radiator as it radiates with 100 per cent efficiency. On the other hand, gases and water vapour are selective absorbers and radiators. As a result, the atmosphere is very transparent to insolation because it does not absorb certain wave length of radiation such as visible light. But it is nearly opaque (good absorber) to long wave terrestrial radiation since gases such as water vapour and carbon dioxide are good absorbers of long wave radiation. The atmosphere is, therefore, heated more by terrestrial radiation than the incoming solar radiation. This also explains why the atmosphere is heated from the ground up instead of vice versa especially in the troposphere.

Conduction

Transfer of heat through matter by molecular activity is called *conduction*. When two bodies of unequal temperature are in contact with one another, there is a flow of energy from the warmer to the cooler body. This transfer of heat continues until both the bodies attain the same temperature or the contact is broken.

The ability of substances to conduct heat

varies. Metals are good conductors. Air, on the other hand, is a poor conductor of heat. Consequently, conduction is important only in the lower layers of the atmosphere where the air is in the direct contact with the earth's surface. As a means of heat transfer in the atmosphere as a whole, it is the least significant.

Convection

Transfer of heat by the movement of a mass or substance from one place to another is called *convection*. Convective motions are possible only in liquids and gases.

When the air in the lower layers of the atmosphere gets heated either by terrestrial radiation or conduction, it expands. Owing to decrease in density, it moves upward. Continuous ascent of the heated air mass pushes aside the air at the higher levels. As a result, the pushed air mass moves horizontally towards cooler areas and gradually descends down due to increasing density. Due to continuous ascent of the heated air, a vacuum is created in the lower layers of the atmosphere. Cooler air mass moves horizontally near the earth's surface to fill up this void. Reaching the heated region, it also warms up and rises. Hence, cyclic movements associated with the convectional currents in the atmosphere transfer heat from the lower layers to the upper layers and heat up the atmosphere.

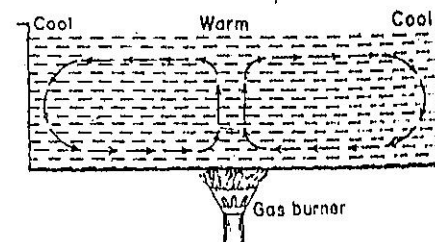


FIG. 11.3 Convection

Heat Budget

The average temperature of the earth remains rather constant. It has been possible because of the balance between the amount of incoming solar radiation and the amount of terrestrial radiation returned to space. This balance of incoming and outgoing radiation has been termed the earth's *heat budget*.

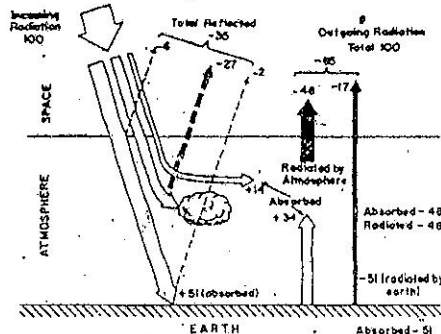


FIG. 11.4 Heat budget

Let us assume that the total heat received at the top of the atmosphere is 100 units. Roughly 35 units are reflected back to space even before reaching the earth's surface. Of these, 27 units are reflected back from the top of the clouds and 2 units from the snow and ice-covered areas of the earth. The reflected amount of radiation is called the *albedo of the earth*.

The remaining 65 units are absorbed, 14 units within the atmosphere and 51 units by the earth's surface. The earth radiates back 51 units in the form of terrestrial radiation. Of these, 17 units are radiated to space directly and the remaining 34 units are absorbed by the atmosphere (6 units absorbed directly by the atmosphere, 9 units through convection and turbulence and 19 units through latent heat of condensation). Forty-eight units absorbed by the atmosphere (14 units from

insolation +34 units from terrestrial radiation) are also radiated back into space. Thus, the total radiation returning from the earth and the atmosphere respectively is $17+48 = 65$ units which balance the total of 65 units received from the sun. This is termed the *heat budget* or *heat balance of the earth*.

Latitudinal Heat Balance

Although the earth as a whole maintains a balance between the incoming and outgoing radiation, still its ratio is not uniform all over the earth. It has been discussed earlier that the amount of insolation gradually decreases from the equator towards the poles. Similarly, the amount of terrestrial radiation also varies. At latitudes below 40 degrees more solar radiation is received than is lost to space by the earth. The opposite is true for higher latitudes where more heat is lost than the received. The tropics, therefore, should have been getting progressively hotter and the poles getting progressively cooler. But this is not so. The atmosphere and the oceans act as giant thermal engines that transfer heat from the tropics towards the poles. Due to imbalance of heat, winds and ocean currents are produced. As most of the heat transfer takes place across the mid-latitudes (30 degrees to 50 degrees), much of the stormy weather is associated with this region. Thus, the transfer of surplus energy from the lower latitudes to the deficit energy zone of the higher latitudes, maintains an overall balance over the earth's surface.

Temperature

Usage of terms heat and temperature are quite often confusing. Essentially *heat* is a form of energy which makes things hotter. In other words, it refers to the quantity of energy. Temperature measures the

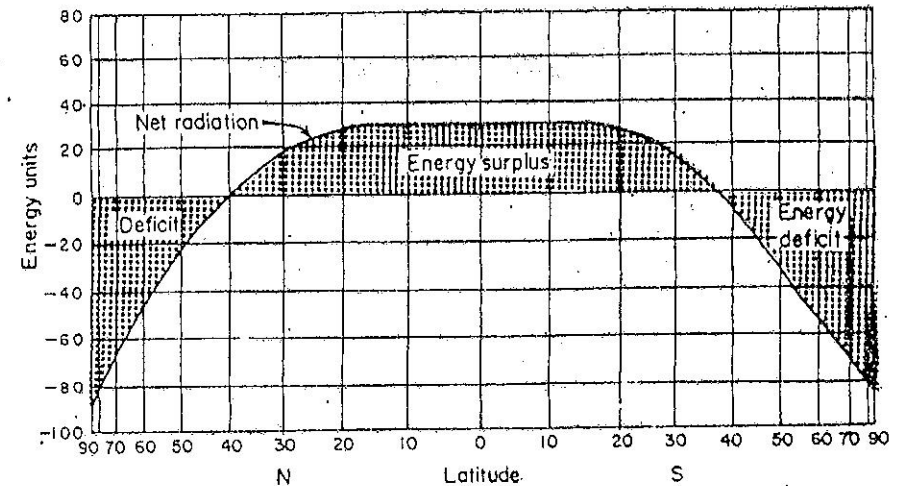


FIG. 11.5 Latitudinal heat balance

intensity of heat, i.e., the degree of hotness. Hence, the two concepts are distinct. Nevertheless, they are related because gain or loss of heat is necessary to raise or lower the temperature. Besides, difference in temperature it determines the direction of heat flow.

Factors Controlling Temperature

While discussing insolation we have examined the single greatest cause for temperature variation—difference in the receipt of incoming solar radiation which varies with the latitude. They are responsible for warm temperatures in the tropics and gradual decrease in temperature towards the poles. However, latitude is not the only factor controlling temperature. If it were so, all places along the same parallel would have identical temperatures. Several other factors such as differential heating of land and water, prevailing wind, ocean currents, altitude and aspects of slope (degree of slope and direction facing the sun) also exert strong

influence upon temperature. This creates temperature anomaly, about which you will know more later in this chapter.

Land and Water

Since air is heated more by terrestrial radiation, differential heating of land and water surfaces cause variations in the temperature of the air above. Land mass is heated and cooled more rapidly and to a greater degree than water. Hence, the temperature of the air resting over a land mass differs markedly from that of the air resting over an expanse of water in the same latitude. Greater extremes of temperature are felt over the land than over the oceans. The temperature contrasts between the continents and the oceans are greater during winter than during summer.

Prevailing Winds

A windward coastal location will experience the full moderating influence of the oceans—cool summer and mild

winters. On the other hand, an inland station on the same latitude or a leeward coastal location will have a more continental temperature regime because the winds do not bring oceanic influence to it.

Ocean Currents

Ocean currents influence temperature of adjacent land areas considerably. Warm currents raise the temperatures of the coastal areas, whereas cold currents lower them.

In the higher latitudes, e.g., in Eurasia and North America, the eastern coasts have much lower temperatures than the corresponding western coasts. The North Atlantic Drift, an extension of the warm Gulf Stream keeps winter time temperatures in Great Britain and much of western Europe warmer than one would expect for their latitudes. Because of the prevailing westerly winds, the moderating effects of the ocean currents are carried far inland. For example, Berlin (52° North latitude) has a mean January temperature similar to New York, (40°N. lat.) in spite of the fact that it lies about 12° degrees latitude north of New York.

The influence of the cold currents is most pronounced in the tropics or during the summer months in mid-latitudes. For example, the cold Benguela currents off the western coast of southern Africa moderate the tropical heat.

Altitude

The atmosphere is heated mainly from below. The lowest layer of the air in contact with the earth's surface is, therefore, the warmest. As we go higher, the temperature gradually decreases and the air becomes cooler. The normal lapse rate is roughly 1°C for every 165 metres of ascent. There are variations from the

normal at different times of the day, in different seasons and in different locations of places.

The two cities of Quito and Guayaquil both in Ecuador are near the equator and are relatively close to one another. However, the annual mean temperature at Guayaquil is 25.5°C as compared to Quito's mean of 13.3°C. This difference is mainly due to the difference in elevation of the two cities. Guayaquil is only 12 metres above sea level, whereas Quito is higher in the Andes Mountains at 2,800 metres.

Aspects of Slope: Direction of the slope and its angle control the amount of solar radiation received locally. Slopes more exposed to the sun receive more solar radiation than those away from the sun's direct rays. In many valleys, settlements and cultivation are, therefore, concentrated on southern slopes, whereas northern slopes remain forested. In our country this phenomenon is well observed in the Himalayan region.

Due to these factors, distribution of temperature over the earth is not uniform. It varies horizontally as well as vertically.

Horizontal Distribution of Temperature

By horizontal distribution we mean the distribution of temperature across latitude. It is shown on a map by isotherms. An isotherm (*isos* equal, *therms* temperature) is an imaginary line joining places having equal temperatures, reduced to sea level to eliminate the effects of altitude.

Isotherms have three general characteristics: (i) isotherms trend east-west, generally following the parallels, (ii) isotherms take sudden bends where land-water contrasts are maximum, and (iii) the spacing of isotherms indicates the latitudinal thermal gradient, i.e., steepness of temperature change.

Isotherms have close correspondence

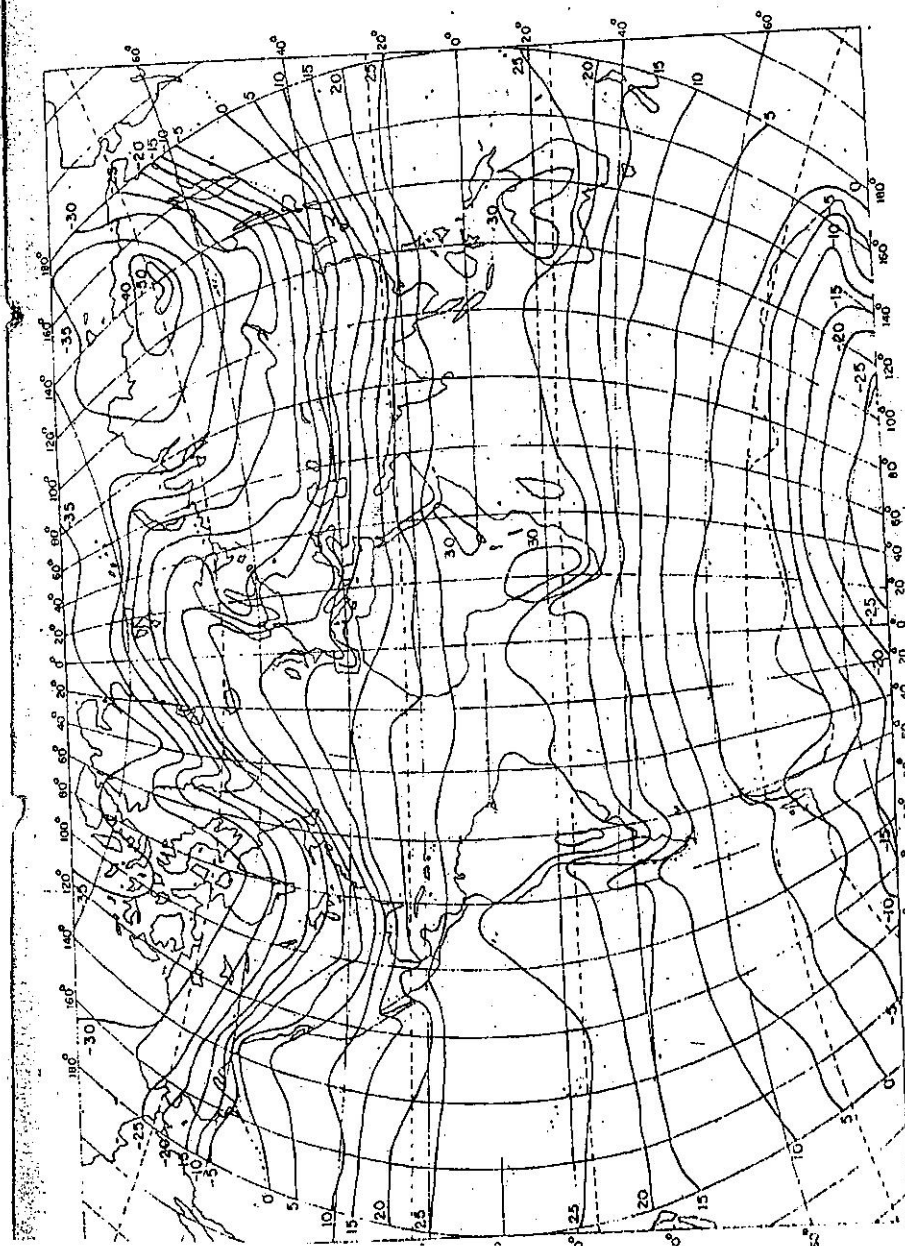


FIG. 11.6 Distribution of temperature (January)
(Temperature in °C)

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with the parallels of latitudes mainly because same amount of insolation is received by all the points located on the same latitude. Owing to unequal distribution of insolation on the earth's surface, the temperature is highest in the tropics and decreases gradually towards the poles. Due to differential heating of land and water, temperature above the oceans and land masses varies even on the same latitude. Isotherms, therefore, bend slightly while crossing from land mass to oceans and vice versa.

As regards the spacing of the isotherms, close spacing indicates a rapid change in the temperature and wide spacing means slow change.

By examining isothermal maps for January and July, changing patterns of global temperature with reference to the apparent movement of the sun, distribution of land and water, ocean currents and prevailing winds can be studied. For most places on the earth, January and July represent the seasonal extremes of temperature and for this reason, these months are most often selected for analysis.

January

At this time, when the sun shines vertically overhead near the Tropic of Capricorn, it is winter in the Northern Hemisphere and summer in the Southern Hemisphere. Temperature is, therefore, high over the land mass in the Southern Hemisphere rising over 30°C in four areas—North-west Argentina, East-central Africa, Borneo and Central Australia. In the Northern Hemisphere, land mass is cooler than the oceans. As a result, lowest temperature occurs in North-east Asia.

As the air over the ocean is warmer than that over the land masses in the Northern Hemisphere, the isotherms bend

equatorward while crossing the land masses and poleward while crossing the oceans. In the Southern Hemisphere, the conditions during this season are just the reverse. Therefore, the isotherms bend equatorward while crossing the oceans and poleward while crossing the land masses. Due to the presence of vast expanse of land masses, isotherms are irregular and closely spaced in the Northern Hemisphere. They are more regular and widely spaced in the Southern Hemisphere.

July

During this period, the sun shines vertically overhead near the Tropic of Cancer. It is summer for the Northern Hemisphere and winter for the Southern Hemisphere. Maximum temperature of over 30°C occurs entirely in the Northern Hemisphere between 10° and 40°N . latitudes. The areas include the South-eastern USA, the Sahara, Arabia, Iraq, Iran, Afghanistan, large part of China and a small part of South India. However, the lowest temperature, i.e., below zero degree Celsius is also recorded in the Northern Hemisphere in the central parts of Greenland.

The relative temperature of air over the two hemispheres are just the opposite of what they were in the month of January. In the Northern Hemisphere, the isotherms bend equatorward while crossing the oceans and poleward while crossing the land masses. In the Southern Hemisphere, it is vice versa. Isotherms reveal wider spacing on the ocean than on the continents.

It is thus apparent from the analysis of the isotherms that there is a latitudinal shifting of temperature distribution because of the seasonal migration of the sun's vertical rays. Due to a regular decrease of insolation from the equator to

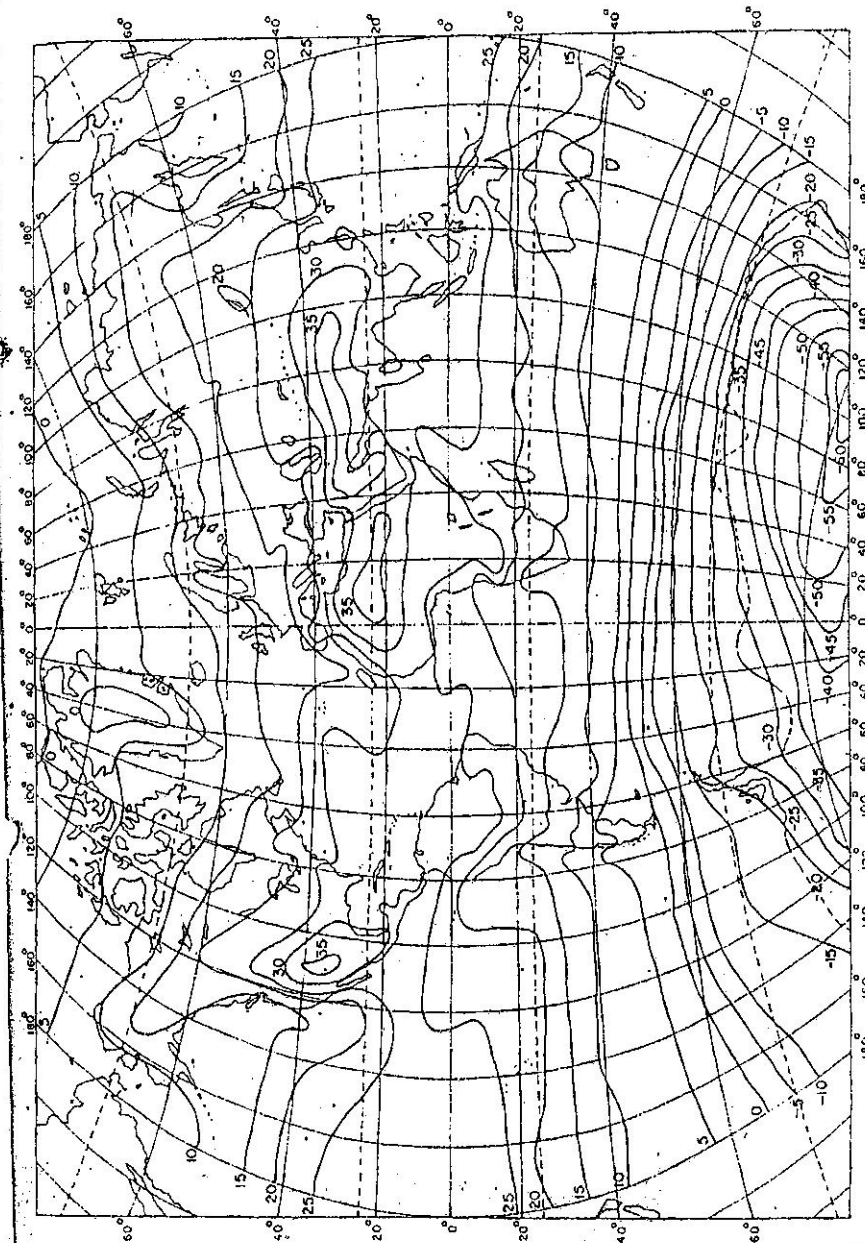


FIG. 11.7 Distribution of temperature (July)
(Temperature in $^{\circ}\text{C}$)

the poles, the highest values occur in the low latitudes and the lowest values near the poles. Isotherms reveal marked contrast in the distribution pattern of temperature between the two hemispheres mainly due to the distribution pattern of land and water in the two hemispheres, and their differential heating. Isotherms are straighter and widely spaced in the Southern Hemisphere than in the Northern Hemisphere because of the broad expanse of water in the former hemisphere. Similarly seasonal contrasts in temperature are also less pronounced in the Southern Hemisphere. The difference between the average temperature of the warmest and the coldest month is called the *annual range of temperature*. It presents the extent of variations in temperature. Annual range of temperature is large over the continents in the middle and high latitudes of the Northern Hemisphere. The range of over 38°C occurs near Verkhoyansk in Russia which happens to be the highest range.

Temperature Anomaly

As mentioned earlier, temperature varies even along the same parallel of latitude because of the factors like altitude, land and water contrasts, prevailing winds and ocean currents. The difference between the mean temperature of any place and the mean temperature of its parallel is called the *temperature anomaly* or *thermal anomaly*. It thus, expresses deviation from the normal.

The largest anomalies occur in the Northern Hemisphere and the smallest in the Southern Hemisphere. The anomaly is said to be negative when the temperature at a place is less than the expected temperature of the latitude. The anomaly is positive when the temperature at a place is more than the expected temperature of

the latitude.

For the year as a whole the anomalies are negative over the continents from about 40° latitude towards the poles and positive towards the equator. On the ocean, the anomalies are positive poleward from about 40° latitude and negative towards the equator.

Vertical Distribution of Temperature

The most characteristic feature of the vertical distribution of temperature is that it decreases with increasing height. Since the atmosphere is heated mainly by the terrestrial radiation, the atmospheric layer immediately overlying the earth's surface receives the maximum heat. It is, therefore, the warmest. But as we go higher and higher, the temperature gradually decreases and the air becomes cooler because increasingly higher layers receive a lesser amount of heat. What is the normal rate of decrease in temperature with increase in altitude under normal conditions?

Inversion of Temperature

Occasionally the temperature in the lower layers of the air increases instead of decreasing with elevation. It occurs particularly on cold winter nights, when the sky is clear, the air is very dry, and there is no wind. These conditions permit quick radiation of heat from the earth's surface as well as from the lower layers of the atmosphere. This results into cooling of the air near the earth's surface. Being heavy and dense, it rests there sometimes for a number of days. The upper air which loses its heat less rapidly remains comparatively warm. The movement of colder air over low altitudes also brings about similar results by lowering the ground temperatures. Thus, there is reversal in the vertical distribution of temperature, which

is known as the *inversion of temperature*. This phenomenon is specially observed in the intermontane valleys.

During long winter nights the valley floor and the mountain slopes radiate heat quickly and the surface becomes cold. The air resting above the surface also cools down quickly and becomes dense. As such it moves down the slope and settles down in the valley bottom replacing comparatively warmer air which is pushed up. Sometimes, the temperature of the air in the valley bottom reaches below freezing point, whereas the air at higher altitude remains comparatively warm. As a result, the trees along the lower slopes are bitten

by frost, whereas those at higher levels are free from it. Due to inversion of temperature, air pollutants such as dust particles and smoke do not disperse in the valley bottoms. It is because of these reasons, houses and farms in intermontane valleys are generally situated along the upper slopes, avoiding the cold and foggy valley bottoms. For example, mulberry planters in the Suwa Basin of Japan and apple growers in the mountain states of the Himalayas avoid lower slopes. Similarly, the hotels at holiday resorts in the Himalayas are built on the upper slopes.

EXERCISES

Review Questions

1. Answer the following questions :

- What is insolation? Why is it called the most important controlling factor of climate?
- Why does the amount of solar energy received at the earth's surface change when the altitude of the sun changes?
- Why do different parallels receive different amount of insolation?
- Why the atmosphere is heated more by terrestrial radiation than by insolation?
- What is meant by the vertical distribution of temperature?

2. Write short notes on :

- Heat-Budget, (ii) Latitudinal heat balance, (iii) Isotherms, (iv) Inversion of temperature, and (v) The lapse rate of temperature.

3. Describe the three basic mechanisms of heat transfer. Which of these mechanisms is the least important meteorologically?

4. What factors control the horizontal distribution of temperature?

5. Answer the following questions about world temperature distribution. You may refer to the January and July Isotherms maps.

- Isotherms generally trend east-west. Why?
- Isotherms shift north and south from season to season. Why?

- (iii) Where do isotherms shift most, over land or water? Explain.
- (iv) Why are isotherms more irregular in the Northern Hemisphere than in the Southern Hemisphere?

6. Complete the following statement with a correct ending:

Sometimes trees at the valley bottom are completely frost bitten while on the higher ground they escape frost altogether because

- (i) the air at the higher level is warmer or since it is able to absorb a greater amount of the incoming heat energy of the sun.
- (ii) the colder air collects at the valley bottom due to its higher density.
- (iv) the frost developed at higher level slips down and collects in the valley bottom, affecting the trees there.

Finding Out

7. Find out the maximum, minimum and mean temperature of your place in different seasons.

Cartographic Work

8. Prepare a temperature graph for your place.

Further Readings

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CHAPTER 12

Atmospheric Pressure, Winds and Airmasses

ALTHOUGH the atmosphere exerts considerable pressure over the earth, we rarely feel it. Similarly of the various elements of weather and climate, changes in air pressure are hardly noticed by us. However, the atmospheric pressure is a very important factor in producing changes in our weather, as it is closely linked with other elements of weather and climate in a cause and effect relationship. Contrasts in temperature cause changes in air density, which are responsible for variations in pressure. These variations cause horizontal movements of air called winds. Winds transport heat and moisture from one region to another and thus help in the occurrence of precipitation and affect both temperature and humidity. Moreover, different climatic types and regions are characterized by distinctive pressure and wind conditions. Atmospheric pressure is, therefore, regarded as one of the most significant factor in weather forecasting.

Measurement of Air Pressure

The atmosphere rests on the earth's surface owing to the gravitational pull of the earth. Hence, it exerts its weight as pressure on the earth's surface. Atmospheric pressure is thus the weight of the column of air at any given place and time. It is measured by means of an instrument called a barometer. It is measured as a force per unit area. The

units used by meteorologists for this purpose are called millibars (mb). One millibar is equal to the force of one gram on a square centimetre. A pressure of 1,000 millibars is equal to the weight of 1,053 kilograms per square centimetre. In other words, it will be equal to the weight of a column of mercury 75 centimetres high. To be exact, the normal pressure at sea level is about 76 centimetres (1013.25 millibars). However, it fluctuates on either side of this value.

The distribution of atmospheric pressure is shown on a map by isobars. An isobar is an imaginary line drawn through places having equal atmospheric pressure reduced to sea level. The spacing of isobars expresses the rate and direction of the pressure changes and are referred to as pressure gradients. Close spacing of isobar indicates a strong pressure gradient, while wide spacing suggests a weak gradient. The pressure gradient may, therefore, be defined as the decrease in pressure per unit distance in the direction in which the pressure decreases most rapidly. There are two types of pressure systems—high pressure and low pressure.

Distribution of Atmospheric Pressure

Distribution of atmospheric pressure is not uniform over the earth's surface. It varies vertically as well as horizontally.

Vertical Distribution

Air being a mixture of gases is highly

compressible. Its density is, therefore, greatest at the lower layers where it is compressed under the mass of air above. As a result, the lower layers of the atmosphere have high density and high pressure. In contrast, the higher layers are less compressed and hence, have low density and low pressure. Air pressure always decreases with increase in altitude, but its rate of decrease is not constant. The density of air depends upon temperature, amount of water-vapour and gravity. Since all these factors are variable, there is no simple relationship between altitude and pressure. However, in general we can say that the atmospheric pressure decreases on an average at the rate of about 34 millibars per every 300 metres of height.

Horizontal Distribution

The distribution of atmospheric pressure across the latitudes is termed global horizontal distribution. Its main feature is its zonal character known as *pressure belts*. On the earth's surface, there are in all seven pressure belts. They are the

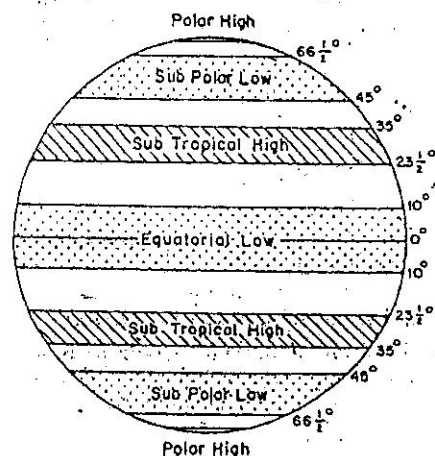


FIG. 12.1 Pressure belts

equatorial low, the sub-tropical highs, the sub-polar lows, and the polar highs. Except the equatorial low, all others form matching pairs in the Northern and Southern Hemispheres.

Due to intense heating, air gets warm and rises over the equatorial region and produces the equatorial low pressure belt which extends from the equator to about 10°N. and S. The equatorial low pressure belt is characterized by extremely low pressure with calm conditions. Surface winds are generally absent since winds approaching this belt begin to rise near its margin. Thus, only vertical currents are found. This belt is also called the *doldrums* because of the extremely calm air movements. Lowest temperatures are found over the poles which cause subsidence of air and hence polar highs. The polar highs are small in area and extend around the poles.

In between the equatorial low and the polar highs, there are the zones of sub-tropical highs and the sub-polar lows. The sub-tropical highs extend from near the tropics to about 35°N. and S. These are caused by subsidence and piling up of the air—the phenomenon which has been explained in the following pages. The descending air currents feed the winds blowing towards adjoining low pressure belts. A calm condition with variable and feeble winds is created in these high pressure belts called 'Horse latitudes'. In early days, the sailing vessels with the cargo of horse found it very difficult to sail under such calm conditions. They used to throw horses in the sea to make their vessels light. The sub-polar lows are located between 45°N. and S. to the Arctic and the Antarctic circles. The winds coming from the sub-tropics and polar areas, converge and rise in a zone between 45°N. and S. and the Arctic and the

Antarctic circles, respectively. Due to a great contrast between the temperature of the winds from sub-tropical and polar source regions, cyclonic storms or 'lows' are produced in the region.

There are two main causes for the pressure differences resulting into high and low pressure systems. These are: (i) thermal, and (ii) dynamic. In thermal causation, temperature and its variations from the equator to the poles in general is an important factor since a chain of events take place due to heating and cooling of the earth's surface and its atmosphere. When air is heated it expands and hence decrease in its density. This naturally leads to low pressure. On contrary, cooling results in contraction. This increases the density and thus leads to high pressure. Formation of equatorial low and polar highs are examples of thermal lows and thermal highs, respectively.

However, temperature alone is not responsible for the differences in pressure. If it were so, the pressure would have progressively increased from the equator towards the poles. But the actual distribution is somewhat different. There are two intermediate zones of sub-tropical highs and sub-polar lows, and for which the previous explanation does not hold good. Formation of these pressure belts may be explained, by dynamic controls arising out of pressure gradient forces and rotation of the earth. The warm air of the equatorial low pressure belt gradually gets cool in its ascent. Upon reaching upper layers, it starts moving towards the pole. It further cools and begins to subside in a zone between 20 and 35 degrees latitude. Two factors are responsible for the general subsidence of air in this belt. First, cooling of the air results in increased density, which accounts for its subsidence. Second, owing to the rotation of the earth

poleward, directed winds are deflected eastwards which is also called the *Coriolis force* after the name of a French scientist, who first expressed its magnitude quantitatively. The rate of deflection increases with the distance from the equator. As a result, by the time the poleward-directed winds reach 25 degrees latitude, they are deflected into a nearly west to east flow. It produces a blocking effect and the air piles up aloft. This causes a general subsidence in the areas between the tropics and 35°N. and S, developing into high pressure belts.

Location of these pressure belts should not be regarded as fixed since they are based on the annual averages. They are greatly affected by differences in net radiation resulting from apparent movement of the sun and from variations in heating of land and water surfaces. Following the apparent movement of the sun the pressure belts shift. In the Northern Hemisphere during summer the *thermal equator* that is, the belt of highest temperature—would be located north of the geographical equator and the pressure belts, therefore, shift slightly north of their annual average location. During winter the thermal equator is located south of the geographical equator and hence pressure belts shift southward. Opposite conditions prevail in the Southern Hemisphere. The amount of shift is, however, less in the Southern Hemisphere due to the predominance of water. Similarly, distribution of continents and oceans have a marked influence over the distribution of pressure. In winter the continents are cooler than the oceans and tend to develop high pressure centres, whereas in summer they are relatively warmer and develop low pressure. It is just the reverse with the oceans.

Seasonal Distribution of Pressure

Seasonal contrasts in world distribution of

- (iii) Where do isotherms shift most, over land or water? Explain.
- (iv) Why are isotherms more irregular in the Northern Hemisphere than in the Southern Hemisphere?

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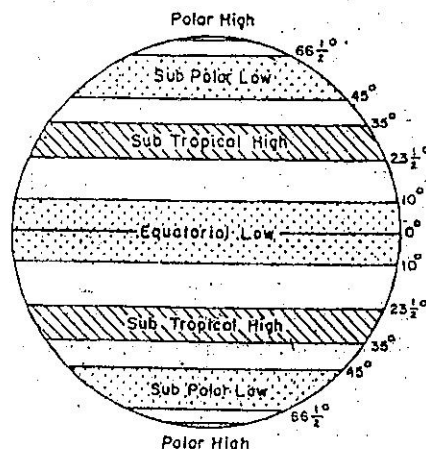


FIG. 12.1 Pressure belts

equatorial low, the sub-tropical highs, the sub-polar lows, and the polar highs. Except the equatorial low, all others form matching pairs in the Northern and Southern Hemispheres.

Due to intense heating, air gets warm and rises over the equatorial region and produces the equatorial low pressure belt which extends from the equator to about 10°N. and S. The equatorial low pressure belt is characterized by extremely low pressure with calm conditions. Surface winds are generally absent since winds approaching this belt begin to rise near its margin. Thus, only vertical currents are found. This belt is also called the *doldrums* because of the extremely calm air movements. Lowest temperatures are found over the poles which cause subsidence of air and hence polar highs. The polar highs are small in area and extend around the poles.

In between the equatorial low and the polar highs, there are the zones of sub-tropical highs and the sub-polar lows. The sub-tropical highs extend from near the tropics to about 35°N. and S. These are caused by subsidence and piling up of the air—the phenomenon which has been explained in the following pages. The descending air currents feed the winds blowing towards adjoining low pressure belts. A calm condition with variable and feeble winds is created in these high pressure belts called 'Horse latitudes'. In early days, the sailing vessels with the cargo of horse found it very difficult to sail under such calm conditions. They used to throw horses in the sea to make their vessels light. The sub-polar lows are located between 45°N. and S. to the Arctic and the Antarctic circles. The winds coming from the sub-tropics and polar areas, converge and rise in a zone between 45°N. and S. and the Arctic and the

Antarctic circles, respectively. Due to a great contrast between the temperature of the winds from sub-tropical and polar source regions, cyclonic storms or 'lows' are produced in the region.

There are two main causes for the pressure differences resulting into high and low pressure systems. These are: (i) thermal, and (ii) dynamic. In thermal causation, temperature and its variations from the equator to the poles in general is an important factor since a chain of events take place due to heating and cooling of the earth's surface and its atmosphere. When air is heated it expands and hence decrease in its density. This naturally leads to low pressure. On contrary, cooling results in contraction. This increases the density and thus leads to high pressure. Formation of equatorial low and polar highs are examples of thermal lows and thermal highs, respectively.

However, temperature alone is not responsible for the differences in pressure. If it were so, the pressure would have progressively increased from the equator towards the poles. But the actual distribution is somewhat different. There are two intermediate zones of sub-tropical highs and sub-polar lows, and for which the previous explanation does not hold good. Formation of these pressure belts may be explained by dynamic controls arising out of pressure gradient forces and rotation of the earth. The warm air of the equatorial low pressure belt gradually gets cool in its ascent. Upon reaching upper layers, it starts moving towards the pole. It further cools and begins to subside in a zone between 20 and 35 degrees latitude. Two factors are responsible for the general subsidence of air in this belt. First, cooling of the air results in increased density, which accounts for its subsidence. Second, owing to the rotation of the earth

poleward, directed winds are deflected eastwards which is also called the coriolis force after the name of a French scientist, who first expressed its magnitude quantitatively. The rate of deflection increases with the distance from the equator. As a result, by the time the poleward-directed winds reach 25 degrees latitude, they are deflected into a nearly west to east flow. It produces a blocking effect and the air piles up aloft. This causes a general subsidence in the areas between the tropics and 35°N. and S. developing into high pressure belts.

Location of these pressure belts should not be regarded as fixed since they are based on the annual averages. They are greatly affected by differences in net radiation resulting from apparent movement of the sun and from variations in heating of land and water surfaces. Following the apparent movement of the sun the pressure belts shift. In the Northern Hemisphere during summer the *thermal equator* that is, the belt of highest temperature—would be located north of the geographical equator and the pressure belts, therefore, shift slightly north of their annual average location. During winter the thermal equator is located south of the geographical equator and hence pressure belts shift southward. Opposite conditions prevail in the Southern Hemisphere. The amount of shift is, however, less in the Southern Hemisphere due to the predominance of water. Similarly, distribution of continents and oceans have a marked influence over the distribution of pressure. In winter the continents are cooler than the oceans and tend to develop high pressure centres, whereas in summer they are relatively warmer and develop low pressure. It is just the reverse with the oceans.

Seasonal Distribution of Pressure

Seasonal contrasts in world distribution of

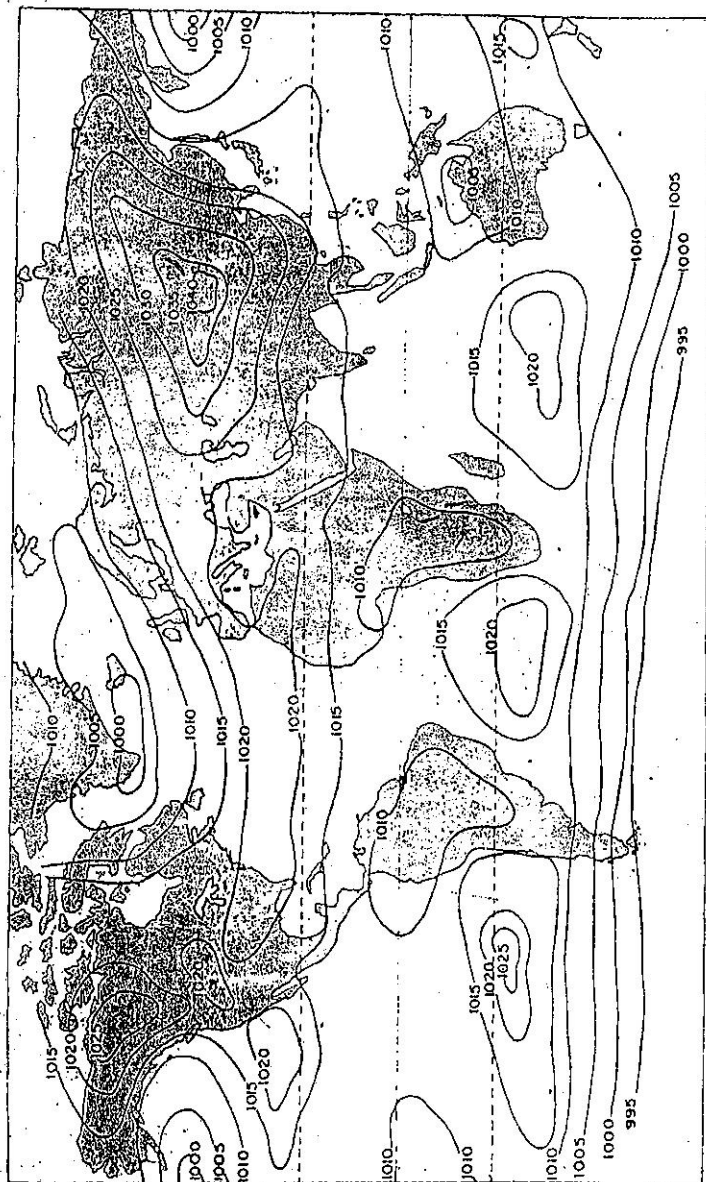


FIG. 12.2 Distribution of pressure (January)
(Figures are given in millibars)

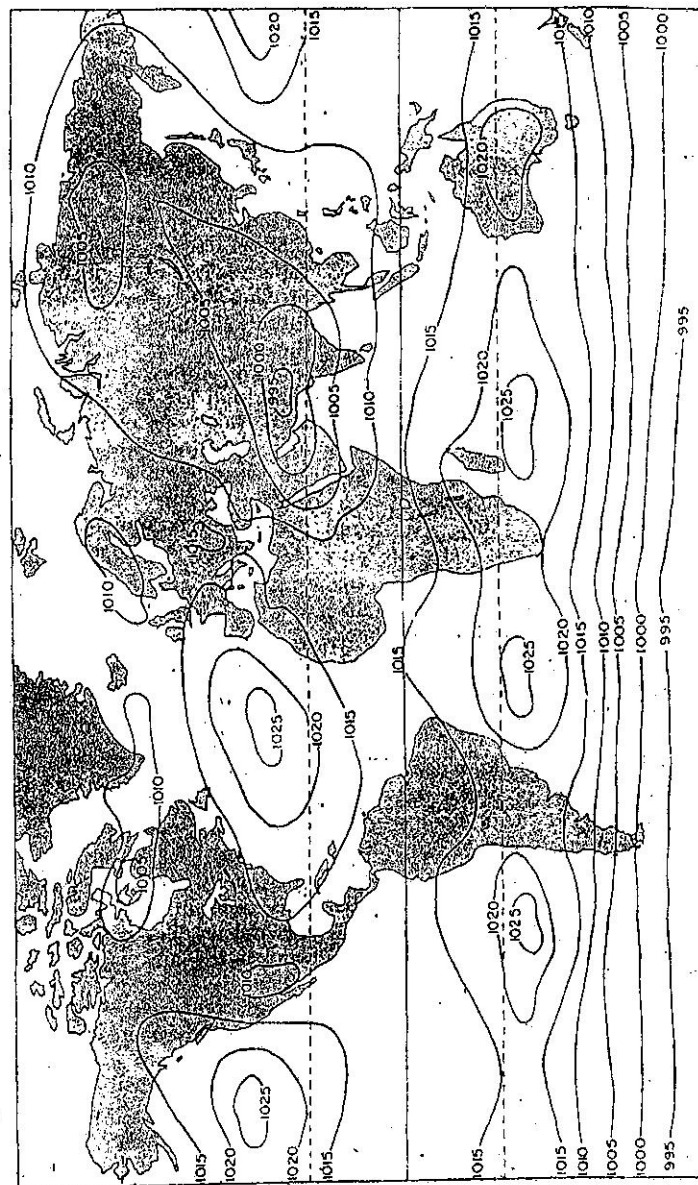


FIG. 12.3 Distribution of pressure (July)
(Figures are given in millibars)

pressure have been shown in Figures 12.2 and 12.3. In January, the equatorial low-pressure belt shifts little south of its mean equatorial position, due to the southward apparent movement of the sun. The lowest pressure pockets occur on the land masses of South America, South Africa and Australia, because land masses become much hotter than the adjoining oceans. Sub-tropical high pressure belt of the Southern Hemisphere is broken over the continents and remains confined to the oceans only. Its development is maximum in the eastern parts of the oceans where the cool ocean currents are effective. In the Northern Hemisphere, a well-developed sub-tropical high pressure area extends over the continents. Finally, sub-polar low of the Southern Hemisphere extends as a trough whereas in the Northern Hemisphere there are two cells of low pressure extending over North Atlantic and North Pacific. These are known as the Icelandic low and the Aleutian low, respectively.

In July, the equatorial low pressure belt shifts north following the apparent movement of the sun. This shift is maximum in Asia. The land masses of the Northern Hemisphere become excessively hot and low pressure areas develop over them. The sub-tropical high pressure belt of the Southern Hemisphere extends continuously. On contrary, in the Northern Hemisphere, it is broken over the continents and remains confined to the North Atlantic and North Pacific Oceans. Sub-polar low is deep and continuous in the Southern Hemisphere, while in the Northern Hemisphere, there is only a faint oceanic low.

Winds

Due to horizontal differences in air pressure, air flows from areas of high

pressure to areas of low pressure. Horizontal movement of the air is called *wind*. It is nature's attempt to balance inequalities in air pressure. The vertical or nearly vertical movement of air is referred to as *air current*. Winds and air currents together comprise a system of circulation in the atmosphere.

Since unequal heating of the earth's surface is one of the main reasons for the pressure differences, solar radiation may be called the ultimate driving force of wind. If the earth were stationary and had a uniform surface, air would flow directly from high pressure areas to low pressure areas. But none of these conditions exist and, therefore, direction and speed of wind are controlled by a combination of factors. These are: the pressure gradient force, gravity, the Coriolis effect, the centripetal acceleration and friction.

To get anything to change, its velocity requires a net imbalanced force in one direction. The force that drives the winds, results from horizontal pressure differences, which is produced from the region of higher pressure towards the area of lower pressure and is known as the *pressure gradient force*. The greater the difference in pressure between two points, the steeper is the pressure gradient and the higher is the wind speed. Since the direction of the force is from higher to lower pressure area and perpendicular to the isobars, the initial tendency of the wind is to blow parallel to the gradient and at right angles to the isobars.

Due to rotation of the earth, winds do not cross the isobars at right angles as the pressure gradient force directs but get deflected from their original path. This deviation is the result of the earth's rotation and is called the *Coriolis effect* or *Coriolis force*. Due to this effect winds in the Northern Hemisphere get deflected to the

right of their path. It is known as the Ferrel's Law. The Coriolis force changes wind direction but not its speed. It is noteworthy that this deflection force does not seem to exist until the air is set in motion and it increases as the wind speed increases.

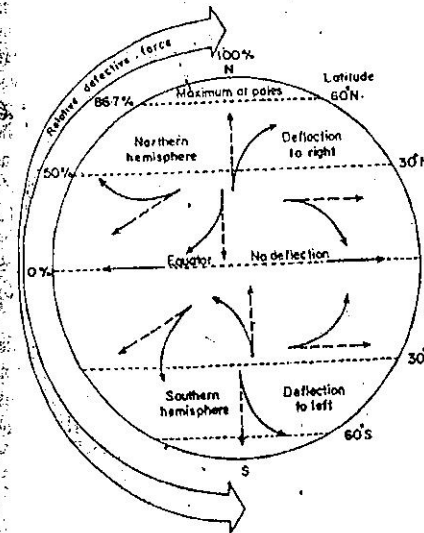


FIG. 12.4 Deflection of winds by Coriolis effect

Due to inward acceleration of air towards the centre of rotation on the rotating earth, it is possible for the air to maintain a curved path (parallel to the isobars) about a local axis of high or low pressure. It is known as *centripetal acceleration*.

Along and near the earth's surface wind does not move freely in a horizontal plane due to irregularities in the earth's surface. The roughness of the terrain causes friction which determines the angle at which the air will flow across the isobars, as well as the speed at which it will move. It may also alter wind direction. Over

relatively smooth ocean surface, friction will be low and the air will move at comparatively lower angles to the isobars and hence at a greater speed. Over rugged terrain, friction will be high and, therefore, the angle of the air flow will also be high and the speed much reduced.

Types of Winds

There are some winds which blow throughout the year from one latitude to the other in response to the latitudinal differences in air pressure. These are known as *prevailing winds* or *planetary winds*. Certain winds reverse their direction periodically with season and are called *periodic winds*. There are certain winds in different parts of the world which flow in comparatively small area and have special characteristics. These are called *local winds* and their nomenclature is usually derived from the regional language.

Planetary Winds

These winds blow over the vast area of the

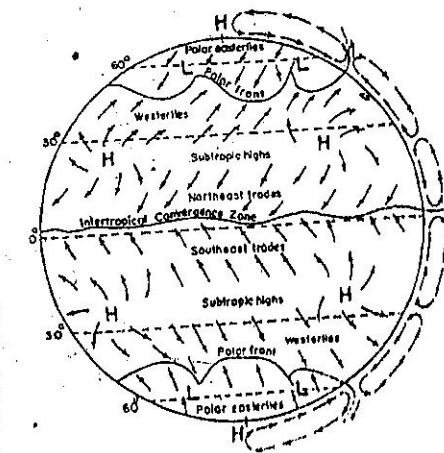


FIG. 12.5 Planetary winds

continents and oceans. The two most well-understood and significant winds for climate and human activities are the trade winds and the westerly winds.

The Trade Winds

The winds blowing from the sub-tropical high pressure areas (30°N. and S.) towards the equatorial low pressure belt are the extremely steady winds known as the *trade winds*. The name trade comes from the German word *trade* meaning 'track'. To blow trade means 'to blow steadily in the same direction and in a constant course'. Its nomenclature has nothing to do with the English word trade, which means business or commerce. These winds should have blown from the north to the south in the Northern Hemisphere and from the south to the north in the Southern Hemisphere. But the Coriolis effect and the Ferrel's Law explain how these winds are deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. Thus, they flow as the north-eastern trades in the Northern Hemisphere and the south-eastern trades in the Southern Hemisphere.

Trade winds have contrasting properties in different parts. In the area of their origin they are descending and stable. The poleward part is therefore dry. As they reach the equator, they become humid and warmer after picking up moisture on their way. They become unstable and produce rainfall. Near the equator, the two trades clash with each other and on the line of convergence they rise and cause heavy rainfall. The eastern parts of the trade winds associated with the cool ocean currents, are drier and more stable than the western parts of the ocean.

The Westerlies

The winds blowing from the sub-tropical

high pressure belts towards the sub-polar low pressure belts are known as *Westerlies*. They blow from south-west to north-east in the Northern Hemisphere and north-west to south-east in the Southern Hemisphere.

In the Northern Hemisphere, vast land masses with their irregular relief and changing seasonal patterns of pressure tend to obscure the general westerly airflow. The westerlies of the Southern Hemisphere are stronger and more constant in direction than those of the Northern Hemisphere, because of the vast expanse of water. The westerlies are best developed between 40° and 65°S. latitudes. These latitudes are often called *Roaring Forties*, *Furious Fifties*, and *Shrieking Sixties*, which are dreaded terms for navigators.

The poleward boundary of the westerlies is highly fluctuating. There are many seasonal and short-term fluctuations. These winds produce spells and variabilities in weather.

Periodic Winds

The winds changing their direction periodically with change in season are called periodic winds. Monsoons are the best example of large scale modification of the planetary wind system. Land and sea breeze, and mountain and valley breeze also come under this category.

Monsoon Winds

The word monsoon has been derived from the Arabic word '*Mausim*' which means season. The monsoon winds thus refer to wind systems that have a pronounced seasonal reversal of direction.

Traditionally, monsoon winds were explained as land and sea breezes on a large scale. Thus, they were considered convectional circulation on a giant scale.

Unfortunately this explanation does not provide an adequate basis for understanding the workings of the system. Among the current theories of origin of the monsoon, the one proposed by Flohn has the widest acceptance. Accordingly, the monsoon is a seasonal modification of the general planetary wind system. The Asiatic monsoon regime is a consequence of the interaction of both planetary and regional factors, both at the surface and in the upper troposphere.

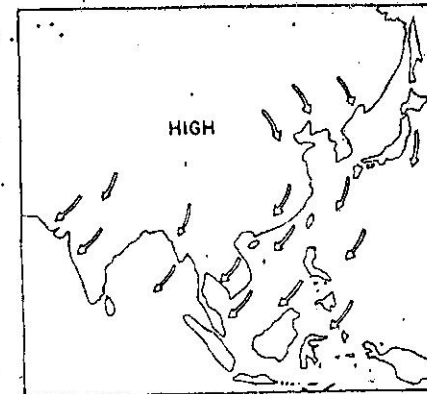
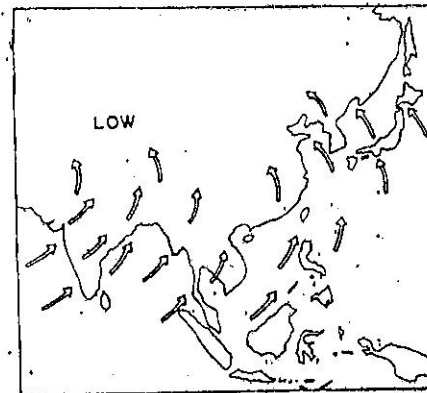


FIG. 12.6 Monsoon winds

During summer, the sub-tropical high pressure belt and the thermal equator are displaced northward in response to the changing pattern of solar heating of the earth. In Southern Asia this movement is magnified by the effects of the vast land mass. The equatorial westerlies embedded in tropical easterlies also move northward. From the ocean, they move towards the land mass and blow over the Asian continent. These are the south-westerly summer monsoon. During winter, the sub-tropical high pressure belt and the thermal equator retreat southward. The normal trade wind is re-established. This is winter monsoon.

The monsoon winds blow over India, Pakistan, Bangladesh, Myanmar, Sri Lanka, Arabian Sea, Bay of Bengal, South-Eastern Asia, Northern Australia, China and Japan.

The summer monsoon is characterized by highly variable weather with frequent spells of drought and heavy rains. The winter monsoon is a gentle drift of air in which the winds generally blow from the north-east. Retreating monsoon cause sporadic rainfall specially in the north-eastern parts and the Tamil Nadu coastal areas of India. Outside India, in the eastern Asiatic countries such as China and Japan, the winter monsoon is stronger than the summer monsoon. Along the coast, the cold continental dry air masses and warm oceanic humid air masses clash and produce heavy cyclonic rains.

Land and Sea Breezes

The land and sea breezes affect only a narrow strip along the coast. During daytime, the land gets more heated than the adjacent sea and develops low air pressure. The sea being cool, develops a comparatively higher pressure. The warm air of the land being lighter ascends and its

place is taken by the cooler air coming from the sea, which is called *sea breeze*. At the higher elevation, warm air gets cooled and moves towards the sea. Hence, sea breezes blow during day at the lower level and moderate the weather of the coastal

fringe. At night, rapid radiation makes the land cooler than the adjoining sea. This results in high pressure over the land and low pressure over the sea. Air starts blowing from land to sea and is known as *land breeze*.

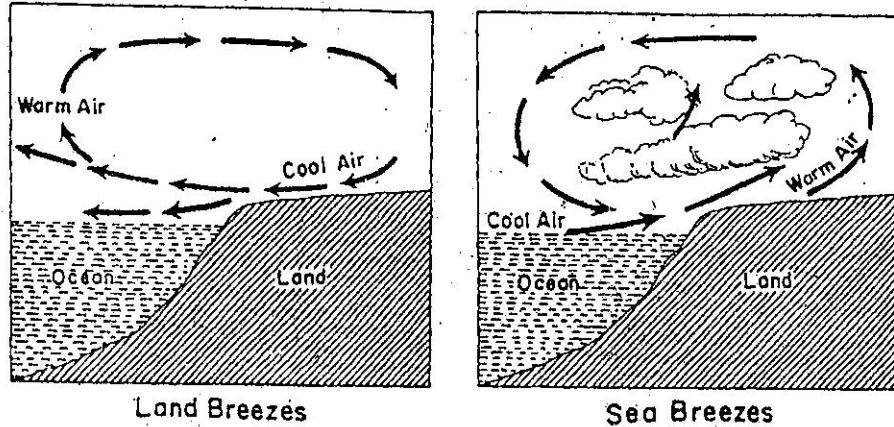


FIG. 12.7 Land and sea breezes

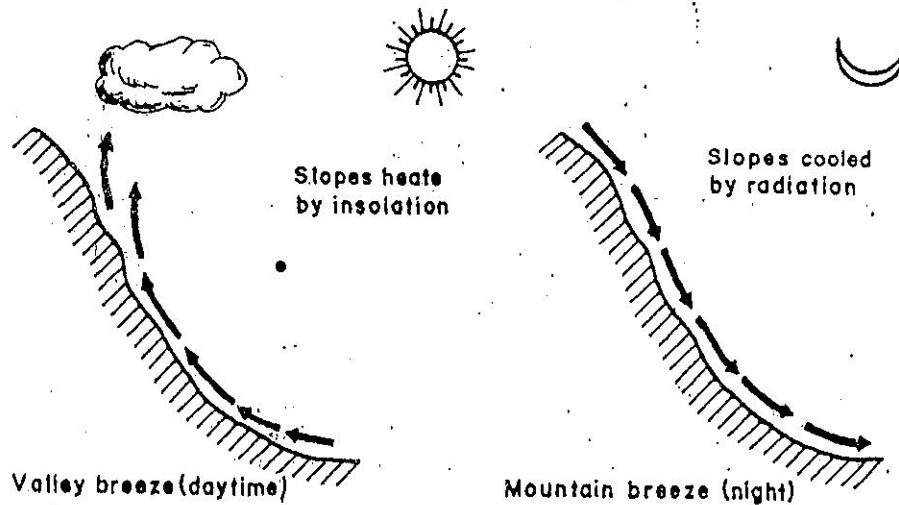


FIG. 12.8 Mountain and valley breezes

Mountain and Valley Breezes

A diurnal or daily wind similar to land and sea breezes occurs in most mountainous regions. During day time the slope of the mountain is heated more than the valley floor. As such the air from the valley flows up the slope. This is known as *valley breeze*. After sunset the pattern is reversed. Rapid loss of heat through terrestrial radiation along the mountain slopes results in sliding of cold dense air from higher elevations to valleys. This is called *mountain breeze*.

Local Winds

Local winds develop as a result of local differences in temperature and pressure. They affect small areas and are restricted to the lowest levels of the troposphere.

Loo

in the plains of northern India and Pakistan, sometimes a very hot and dry wind blows from the west in the months of May and June, usually in the afternoons. It is known as *loo*. Its temperature invariably ranges between 45°C and 50°C. It may cause sunstroke to people.

Foehn and Chinook

Foehn is a hot wind of local importance in the Alps. It is a strong, gusty, dry and warm wind which develops on the leeward side of a mountain range. Due to regional pressure gradient, stable air is forced to cross the barrier. Ascending air sometimes causes the precipitation on the mountains and descends on the leeside. It warms and becomes dry. The temperature of the wind is from 15° to 20°C. The wind helps animal grazing by melting snow and hastens the ripening of grapes. Similar kind of winds in USA and Canada move

down the west slopes of the Rockies and are known as *chinooks*. The word *chinook* literally means 'snow eater'. It is beneficial to ranchers east of the Rockies as it keeps the grasslands clear from snow during much of the winter.

Mistral

During winter, areas adjacent to highlands may experience a local cold wind which originates over the snowcapped mountains or highlands and blows down the valley. These winds have been given local names. The most famous is the *mistral* that blows from the Alps over France towards the Mediterranean Sea. It is channelled through the Rhone Valley. It is a very cold and dry wind with high velocity. Even though the skies are clear, the mistral brings down the temperature below freezing point. Its speed is so great that orchards and gardens have to be protected from it by thick hedges of cypress trees. Many small houses have their doors and windows only on the south-eastern side.

Upper Air Circulation

In the mid-latitude, high-speed winds known as *jet streams* blow from west to east in the upper troposphere near the tropopause. The *jet streams* are narrow meandering bands of swift winds which are embedded in the prevailing westerlies and encircle the globe. They may range from 40-160 kilometres in width and 2-3 kilometres in depth. Average wind speed are very high with a lower limit of about 120 kilometres per hour in winter and 50 km per hour in summer. These jet streams also have cores where speed is much greater.

There are two main jet streams. They are (i) the sub-tropical jet stream, and (ii) the mid-latitude or polar front jet stream. The

sub-tropical jet stream is located over the low latitude margins of the westerlies. It persists through most of the year. It is produced by the rotation of the earth. At the equator, the rotation produces greatest velocity in the atmosphere. As a result the rising air which spreads out northwards and southwards, moves faster than the latitudes over which it is blowing. It is deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere, and at about 30° latitude it becomes concentrated as the sub-tropical jet streams.

The mid-latitude or polar front jet is produced by a temperature difference and is closely related to the polar front about which you will know in detail in Chapter 12 of this book. It has a more variable position than the sub-tropical jet. In summer, its position shifts towards the poles and in winter towards the equator. Can you explain why?

Although jet streams are not yet completely understood, they seem to have an important influence on our weather conditions. They play important role in the possible formation, steering or intensifying weather phenomena such as cyclones, anticyclones, hurricanes, typhoons and other weather conditions. Usually there are severe storms when jet streams interfere with surface wind systems. Jet streams are also used by aviators if they have to fly in the direction of the flow of the jet streams.

Air Masses

Most of the major weather changes take place due to the advances and interaction of air masses and of the processes involved therein.

An *air mass* is a large body of air whose physical properties especially temperature and moisture content are relatively uniform horizontally. Normally, an air mass extends over hundreds of kilometres

and consists of several layers, each having homogeneous conditions. For acquiring such an uniformity, the air must rest for sometimes over a surface which has fairly homogeneous conditions. Regions where homogeneous air masses tend to be created are known as *source regions*. A large land mass or water body which has evenly distribution insolation provides a suitable location for the development of an air mass. Some of the well-known source regions are sub-tropical and tropical oceans, i.e., low-latitude deserts like the Sahara in the summer and the continental interiors especially those of North America and Eurasia in the winter. Another prerequisite for the development of an air mass is large scale subsidence over the source region. Subsiding air over a homogeneous source region gradually acquires the characteristics of the region and retains them even when it moves away. The heat and moisture properties of the air mass may, however, change when it moves over other surface conditions. An air mass is said to be *cold* when it is colder than the surface over which it rests or is moving. An air mass is said to be *warm* when it is warmer than the surface over which it rests or is moving.

Air masses are classified on two bases: (i) nature of the source region; and (ii) air mass modifications. On the basis of the nature of the source region, air masses may broadly be grouped under two categories—*tropical* and *polar*. Since source regions may either be oceans or continents, further sub-divisions introduce four secondary types—*maritime tropical*, *continental tropical*, *maritime polar*, and *continental polar*. Maritime air masses contain high humidity and produce large amount of precipitation. Continental air masses on the other hand, are dry and produce less amount of precipitation.

Eventually, air masses are modified as they move away from their source regions. There are two main types of modifications: *thermodynamic* and *dynamic or mechanical*. When an air mass is heated or cooled from below due to transfer of heat between the ground and the base of the air mass, it is known as *thermodynamic* change. The degree of change is determined by the nature of the underlying surface, the path of movement of an air mass, the duration of travel and the addition or abstraction of moisture. When a warm air mass moves over a cold surface, its lower layers become cold. It produces a temperature inversion which greatly limits the vertical extent of the cooling. As a result, a condition of stability is created, which inhibits condensation and precipitation. Such changes are experienced by tropical air masses. On the contrary, when a cold air mass moves over a warm surface, its lower layers become warm. It increases air mass instability and causes convection. This leads to the formation of vertical clouds (cumulus) and turbulence in the air. Polar air mass experiences this change.

Changes occur due to addition of moisture in the air mass through evaporation from the surface or by precipitation from an overlying layer of

the air mass. Similarly, abstraction of moisture by condensation or precipitation can also bring about changes in the nature of the air mass. Besides, respective addition or loss of latent heat accompanying condensation and evaporation is another important factor responsible for the changes in the air mass.

Dynamic or mechanical changes involve such modifications which are generally independent of the changes caused by surface cooling or heating. For example, significant modification can result from vertical movements induced by cyclones and anticyclones or surface friction. In a cyclone, convergence and rising of air results into instability conversely, the anticyclones are associated with divergence and subsidence of air currents causing stability. Surface friction intensifies the natural turbulence of air flow providing a ready mechanism for the upward transfer of the effects of thermodynamic changes.

Air masses of different densities do not mix readily and tend to retain their identity as far as temperature and moisture are concerned. The boundary zone of convergence separating the two air masses are called *fronts*. Usually, air mass from one region gradually moves to the other region occupied by some other air mass. When a warmer and lighter air mass moves

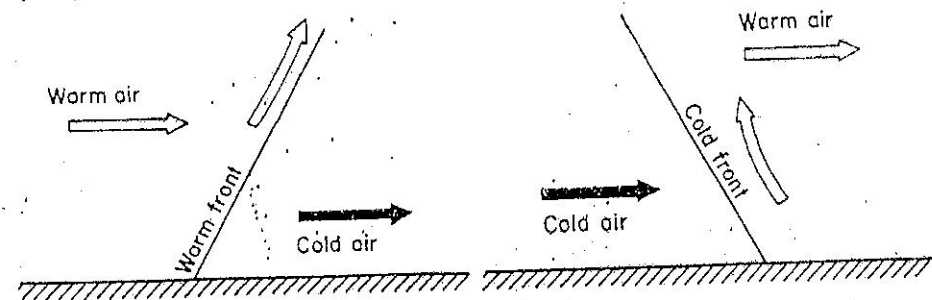


FIG. 12.9 A warm and a cold front

against a cold and more dense air mass, the former rides up over the latter. Such a front is called a *warm front*. On the contrary, if the cold air mass forces its way under a mass of warmer air and pushes the

latter upward, the front will be called a *cold front*.

In the middle latitudes, along the front of the warm and cold airmasses, temperate cyclones are formed.

EXERCISES

Review Questions

1. Answer the following questions:

- (i) How does the knowledge of air pressure help in forecasting weather?
- (ii) What is the standard sea level pressure in millibars?
- (iii) What is a pressure gradient?
- (iv) Distinguish between air currents and winds.
- (v) What are planetary winds?
- (vi) Why does pressure decrease with altitude?
- (vii) What is an air mass? How is it different from wind?

2. Write short notes on:

- (i) Isobars, (ii) The Doldrums, (iii) Mountain and Valley Breezes, (iv) Trade Winds (v) Loo, and (vi) Jet Streams.

3. Briefly describe how the coriolis effect modifies the movement of air.

4. Discuss the pressure belts and prevailing winds.

5. The monsoon is a modification of the general planetary wind system. Explain.

6. Give one term for each of the following:

- (i) An imaginary line drawn through places having equal atmospheric pressure reduced to sea level.
- (ii) Air that moves horizontally along the earth's surface.
- (iii) Deflecting force due to rotation of the earth.
- (iv) Winds blowing over south and south-east Asia that are characterized by reversal in wind direction with change in season.
- (v) Winds blowing from the sub-tropical high pressure belts towards the sub-polar low pressure belts.
- (vi) A warm dry wind, known as a snow eater, blowing on the eastern side of the Rocky Mountains.
- (vii) Narrow meandering bands of swift winds which blow in the mid-latitudes near the tropopause.
- (viii) An air mass which originates over tropical oceans.

Finding Out

7. Find out information on some other famous local winds such as simoom, karaburan and bora.

Cartographic Work

8. Study Figs. 10.2 and 10.3 carefully and write in brief about the sea level pressure in January and July.

Further Readings

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CHAPTER 13

Moisture in the Atmosphere

ALTHOUGH the highly variable water-vapour content forms only a small proportion (varying from zero to four per cent) by volume of the atmosphere, it is the most important constituent of the air in deciding weather and climate. Water may be present in the atmosphere in all the three forms (gaseous—water-vapour, liquid—water droplets, and solid—ice crystals). This unique gift of nature to our watery planet and to the biosphere is of great significance for several reasons, some of them are listed below:

1. The amount of water-vapour present in a given volume of air indicates the atmosphere's potential capacity for precipitation.
2. Water-vapour absorbs radiation and, therefore, it is a regulator of heat loss from the earth.
3. The amount of water-vapour present decides the quantity of latent energy stored up in the atmosphere for the growth of storms.
4. The amount of water-vapour present in the atmosphere affects the human body's rate of cooling.

Water-vapour in the atmosphere comes through evaporation from the oceans, lakes, rivers, ice-fields and glaciers, which together comprise about 75 per cent of the earth's surface. Besides these sources,

evaporation from the moist ground, transpiration from plants, and animal respiration also contribute moisture to the atmosphere. By wind and convective movements, the water-vapour evaporated from various sources is carried for long distances in land from the oceans. Under favourable conditions it condenses and precipitates over the earth's surface as rain, snow and hail. If the precipitation is over the oceans, one cycle completes and another begins. However, the precipitation that falls on the land takes more time in completing the cycle. A portion of the precipitation that falls on the land is soaked by the ground. Some of it is absorbed by plants which later on release it into the atmosphere through transpiration. Rest of the water that infiltrates the ground, moves under the surface and finally finds its way into springs, lakes or streams. When the amount of precipitation is more than the earth's ability to absorb it, the additional water flows over the surface into streams and lakes. Eventually, the water that soaks in or runs off finds its way back to the oceans and then to the atmosphere or directly to the atmosphere.

Thus, there is a continuous exchange of water between the oceans, the atmosphere and the continents through evaporation, transpiration, condensation and precipitation. This unending circulation of the water on the earth is called the *hydrologic cycle*. Energy for the operation

of this cycle is provided by the sun. Atmosphere is the vital link between the oceans and the continents in this gigantic system. Huge quantities of water are cycled through the atmosphere each year. However, the atmosphere contains only a minute fraction of the earth's total water supply at any one point of time.

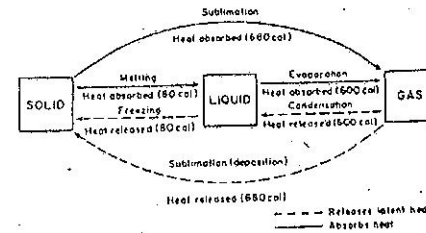


FIG. 13.1 Changes of state

Humidity is the general term which describes the invisible amount of water-vapour present in the air. It may be expressed quantitatively in different ways. The weight of actual amount of water-vapour present in a unit volume of air is called the *absolute humidity*. It is usually expressed as grams per cubic metre of air. Absolute humidity of the atmosphere changes from place to place and from time to time. The ability of air to hold water-vapour depends entirely on its temperature. Warm air can hold more moisture than the cold air. For example, at a temperature of 10°C, one cubic metre of air can hold 11.4 grams of water-vapour. If temperature rises to 21°C, the same volume of air can hold 22.2 grams of water-vapour. Thus, a rise in the temperature of air increases its capacity to retain water-vapour, whereas a fall in temperature decreases it. However, it is not a reliable index because change in temperature and pressure cause changes in the volume of air and consequently the absolute humidity.

Another and perhaps a more useful way is to express humidity as the weight of water-vapour per unit weight of air, or the proportion of the mass of water-vapour to the total mass of air is called the *specific humidity*. Since it is measured in units of weight (usually grams per kilogram), specific humidity is not affected by changes in pressure or temperature.

Yet, another important measure is *relative humidity*, which is the ratio of the air's actual water-vapour content to its water-vapour capacity at a given temperature. This relationship between absolute humidity and the maximum moisture holding capacity of air at a particular temperature is always expressed in percentage. Since relative humidity is based on the air's water-vapour content as well as on its capacity, it can be changed in either of the two ways. First, if moisture is added by evaporation, the relative humidity will increase. Second, a change in temperature will also affect relative humidity and a decrease will cause an increase in relative humidity. Relative humidity determines the amount and rate

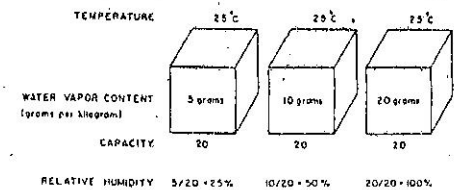


FIG. 13.2 Relative humidity

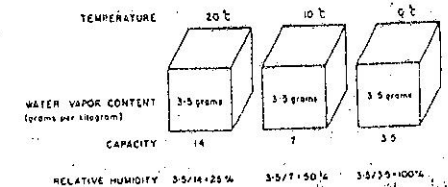


FIG. 13.3 Relative humidity

of evaporation and hence it is an important climatic factor.

Air containing moisture to its full capacity at a given temperature is said to be *saturated*. It means that the air at the given temperature is incapable of holding any additional amount of moisture at that stage. The relative humidity of the saturated air is 100 per cent. If it has half the amount of moisture that it can carry, the air is unsaturated and its relative humidity is only 50 per cent. A given sample of air becomes saturated without any change in its moisture content provided its temperature falls or it cools to the required extent. The temperature at which saturation occurs in a given sample of air or water-vapour begins to change into water is known as *dew point*. Thus, a moist air as in equatorial region has high relative humidity, and dry air as in a desert has low relative humidity although the latter is capable of holding more of it.

Evaporation and Condensation

Evaporation is the process by which water is transformed from liquid to gaseous form. It takes approximately 600 calories of energy to convert one gram of water to water-vapour. One *calorie* is the amount of heat required to raise the temperature of one gram of water to 1°C. The energy absorbed by the water molecules during evaporation is used solely to give them the motion needed to escape the surface of the liquid and become a gas. Because this energy is subsequently released as heat when the vapour changes back into liquid, it is generally referred to as *latent heat*. Conversely, condensation releases this heat energy, which produces violent weather.

The rate of evaporation depends on a number of factors: (i) temperature, (ii) the moisture content or the degree of dryness of air, and (iii) movement of air. If

moisture content is low, air has a potentiality of absorbing and retaining a larger amount of moisture. Air with high humidity has less potentiality, hence evaporation is slow and small in amount. Similarly, increase in temperature increases the water absorption and retention capacity of the given sample of air. Movement of air replaces the saturated layer with the unsaturated layer which has a greater capacity of absorbing moisture. Hence, the greater the movement of air, the greater is the evaporation.

Condensation is the process of change of state from gaseous to liquid or solid state. When moist air is cooled, it may reach a level when its capacity to hold water-vapour is exceeded by the actual amount present in it. Then the excess water-vapour condenses into a liquid or solid form depending upon the temperature. In free air, condensation results from cooling around very small particles termed as *condensation nuclei*. Particles of dust, smoke and salt from the ocean are particularly good nuclei because they absorb water. These particles are termed *hygroscopic* (water-seeking) *nuclei*.

Condensation in air itself can only take place if the temperature of the air is reduced to below the dew point. As the dew point of any mass of air is its saturation point, when its relative humidity is 100 per cent, a little more cooling will bring about the point at the level where condensation takes place, viz., water-vapour changes into clouds or rain. In contrast, when relative humidity is low a large amount of cooling is required to first reach the dew point and then the condensation. If moist air comes in contact with some colder object, the condensation may also take place even when it is close to the dew point. Condensation, therefore, depends on (i) the amount of cooling, and

(ii) the relative humidity of the air. Condensation occurs under varying conditions which in one way or another are associated with change in any of the following variables—air volume, temperature, pressure and humidity. Thus, condensation takes place (i) when the temperature of the air is reduced but its volume remains constant and the air is cooled below the dew point; (ii) if the volume of the air is increased without addition of heat; (iii) when a joint change of temperature and volume reduces the moisture holding capacity of the air below its existing moisture content; or (iv) by evaporation adding moisture to the air. The most common circumstances favourable for condensation are those producing a drop in air temperature.

Adiabatic Temperature Changes

When the air rises, its volume increases due to expansion. Thus, heat available per unit volume is reduced and therefore the temperature also reduces. Such a temperature change which does not involve any subtraction of heat and cooling of air takes place only by ascent and expansion is termed as *adiabatic change*. Vertical displacement of air is the major cause of adiabatic and katabatic temperature changes. Near the earth's surface most processes of change are non-adiabatic because horizontal movements often produce mixing of air and modify their characteristics.

When air rises, temperature decreases. The rate at which temperature decreases in rising air depends upon the moisture content of the air. In unsaturated air, the decrease of temperature with height is twice that in saturated air. This is mainly due to the release of latent heat of condensation after saturation occurs. The rate at which the temperature decreases in

rising unsaturated air is known as *dry adiabatic rate*, and that in the saturated air is called *wet adiabatic rate*.

Forms of Condensation

Forms of condensation can be classified on the basis of temperature at which the dew point is reached. Condensation can take place when the dew point is (i) lower than the freezing point; and (ii) higher than the freezing point. Whereas white frost, snow and some clouds are produced when the temperature is less than the freezing point, dew, fog and clouds result even when the temperature is higher than the freezing point.

Forms of condensation may also be classified on the basis of their location, i.e., at or near the earth's surface and in free air. Dew, white frost, fog and mist come in the first category, whereas the clouds are in the second category. On a clear winter night strong radiation cools the earth's surface very quickly. Cold land surface cools the moist in lower layer of the atmosphere. When the temperature is reduced to the dew point, condensation occurs in the form of dew, frost or fog depending on the amount of moisture involved, the thickness of the cooling air layer and the value of the dew point.

Dew

When the moisture is deposited in the form of water droplets on cooler surface of solid objects such as stones, grass blades and plant leaves, it is known as *dew*. The ideal conditions for its formation are a clear sky, little or no wind, high relative humidity and cold and long nights leading to greater radiation of heat from the earth for its cooling. For the formation of dew, it is necessary that the dew point is above freezing point.

White Frost

When condensation takes place at a dew point which is at or below freezing point (0°C), excess moisture is deposited in the form of minute ice crystals instead of droplets of water. It is called *white frost*. The ideal conditions for the formation of white frost are the same as those for the formation of dew, except that the air temperature must be at or below freezing point.

Fog

Fog is defined as a cloud with its base at or very near the ground. Fogs are of different kinds depending upon the nature of the cooling process. *Radiation fog*, as the name suggests, results from radiation, cooling of the ground and adjacent air.

These fogs are not very thick (10-30 metres). When the moist warm air moves over a cold surface, it is cooled by contact and to some extent by mixing with the cold air associated with the cold surface below. If the cooling is sufficient, fogs will be formed. Since these fogs are a consequence of drop in air temperature during horizontal movement of air, they are known as *advection fog*. Unlike radiation fogs, advection fogs are often thick (300-600 metres deep) and persistent. Fogs are also formed along the front separating cold and warm air masses. Due to convergence, warm air is forced to rise over the cold air and cools. If the resulting clouds yield rain and the cold air below is near the dew point, the excess moisture of the air falling as rain condenses to produce fog at the boundary of the warm and cold air masses. These are called *frontal or precipitation fog*.

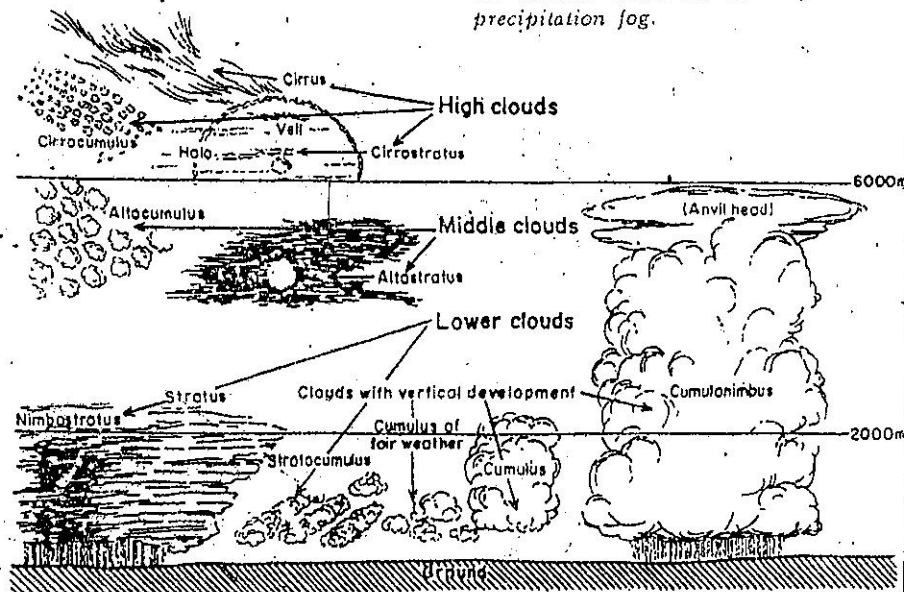


FIG. 13.4 Cloud types

Mist

Mist is also a kind of fog in which the visibility is more than one kilometre but less than 2 kilometres.

Clouds

Cloud is a mass of minute droplets of water or tiny crystals of ice formed by the condensation of the water-vapour in free air at considerable elevations.

Clouds are caused mainly by the adiabatic cooling of air below its dew point. This cooling process is most effectively created by upward movement of light and warm moist air, which in turn reduces pressure, expands and reaches its dew point. With further cooling below the dew or saturation point, condensation takes place in air forming clouds.

Clouds are classified on the basis of (a) their appearance, i.e. the general shape, structure and vertical extent; and (b) their height or altitude.

On the basis of the appearance, the following cloud types may be identified.

Cirrus clouds are high; white and thin. They are composed of ice crystals. They form delicate patches and give a fibrous and feathery appearance. *Cumulus* clouds exhibit a flat base and have the appearance of rising domes. Progressive vertical development of these clouds are usually quite apparent. Such clouds are often described as having cauliflower structure. *Stratus* clouds are best described as sheets of layers that cover much or all of the sky. All the clouds either reflect one of these three basic forms or are combinations or modifications of them.

There are three main groups of clouds according to the average height of their bases. These are: *High clouds* (6,000-12,000 metres); *Medium clouds* (2,000-6,000 metres); and *Low clouds* (ground level-2,000 metres). *Alto* and *Nimbo* are the

other two prefixes which refer to middle level clouds and low clouds of considerable thickness with dark-grey appearance, respectively.

In all there are ten major types of clouds which are grouped here under three main categories arranged according to their height.

I — Low clouds include *stratocumulus*, *stratus*, *nimbostratus*, *cumulus* and *cumulonimbus*.

II — Medium clouds include *altostratus* and *altocumulus*.

III — High clouds include *cirrus*, *cirrostratus* and *cirrocumulus*.

Cloud pictures taken from satellites help in forecasting the weather.

Precipitation

Continuous condensation in free air helps the condensed particles to grow in size. When the resistance of the air fails to hold them against the force of gravity, they fall on the earth's surface. Condensation of water-vapour in the air in the form of water droplets and ice and their falling on the ground is called *precipitation*. This may take place in liquid or solid forms of water. The precipitation in the form of drops of water is called *rainfall*. When the temperature is less than 0°C , precipitation takes place in the form of fine flakes of snow and is called *snow-fall*. Although rain and snow are the two most common forms of precipitation, other forms such as sleet and hail also exist. However, they are limited in occurrence and sporadic in both time and space.

Sleet is frozen raindrops and re-frozen melted snow water. It may be a mixture of snow and rain or merely partially melted snow. When a layer of air with temperature above freezing point overlies a sub-freezing layer near the ground, precipitation takes place in the form of

sleet. The raindrops which leave the warmer air encounter the colder air below. As a result, they solidify and reach the ground as small pellets of ice not bigger than the raindrops from which they are formed.

Precipitation in the form of hard rounded pellets is known as *hail*. Sometimes rapidly ascending air currents lift rain drops to great height above the freezing level. These water droplets freeze easily around small solid particles present in the atmosphere. Once frozen, these small ice granules grow in size and the air is unable to hold them. They start falling down. But the strong air currents again toss them up. In the process they collect more coating of ice, become large and begin the downward journey. Each trip above the freezing level may be represented by an additional layer of ice. Hailstones, therefore, reveal several concentric layers of ice one over the other.

Precipitation Types

On the basis of its origin, precipitation may be classified into three main types—convective, orographic, and cyclonic or frontal. In general, only rain and snow make significant contribution to

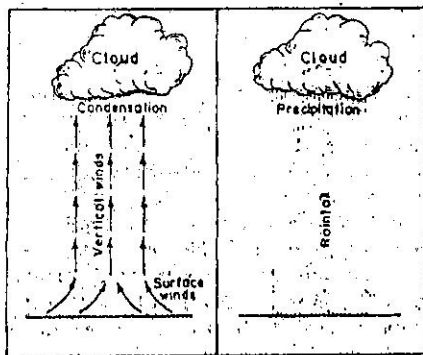


FIG. 13.5 Convective precipitation

precipitation totals. Hence, in many parts of the world the terms rainfall and precipitation are used interchangeably. In fact, precipitation records mostly refer to only rainfall data since snow-fall is less easily measured with the same degree of accuracy.

Convective Precipitation

It is caused by convective ascent of warm and humid air to great heights. Most of it is in the form of rainfall. Due to excessive heating of the earth's surface in summer months, vertical air currents are produced. As the surface air rises, it expands and cools and eventually gets saturated. This is followed by condensation and precipitation. This process releases latent heat of condensation which further heats the air and forces it to continue upward movement. This leads to further condensation and precipitation. Convective precipitation is heavy but highly localized and is associated with minimum amount of cloudiness. Rainfall in the doldrums is of convective nature.

Orographic Precipitation

It occurs when warm and humid air strike landform barriers such as mountain ranges and is forced to rise. The subsequent sequence is similar to that of convective rain. In orographic precipitation, the windward slope of a mountain range gets more precipitation than the leeward slope because the air descends down the slope and gets warmed up. Hence, the leeward



FIG. 13.6 Orographic precipitation

slope is drier and is known as the *rain-shadow area*.

The wide variation in the amount of rainfall at Mahabaleshwar and Pune, only a few kilometres away from each other, is due to the orographic nature of rainfall. Mahabaleshwar situated on the Western Ghats receives more than 600 centimetres of rainfall, whereas Pune lying in the rain-shadow area has only about 70 centimetres.

Cyclonic or Frontal Precipitation

When precipitation is associated with a cyclonic circulation, it is called *cyclonic*. Rainfall and snow-fall of frontal origin are associated with this. When warm and humid air mass converge with the cold air mass, they cause turbulent and stormy conditions, generally followed by precipitation particularly along their fronts.

Distribution of Precipitation

Different places on the earth's surface receive different amounts of precipitation

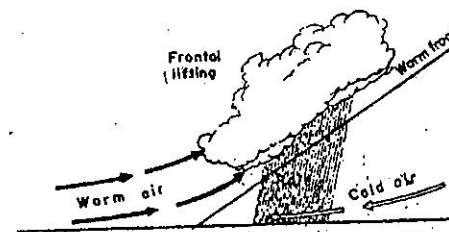


FIG. 13.7 Cyclonic or frontal precipitation

in a year, and that too, in different seasons. Nevertheless, the main features can be explained with the help of global wind and pressure systems, distribution of land and water, and the nature of the relief features.

In general, high latitudes having high pressure associated with subsiding and diverging winds, experience rather dry conditions. On the other hand, the equatorial belt with low pressure and its converging winds, and ascending air receives ample precipitation. Besides wind-pressure systems, the inherent nature of the air involved, is also an important factor in determining the potential for precipitation. Since cold air has low capacity to hold moisture than the warm air, a general decrease in precipitation is revealed with the increasing distance of latitude from the equator towards the poles.

In addition to the latitudinal variation in precipitation, the distribution of land and water complicates the global precipitation pattern. Large land masses in the middle latitudes generally experience a decrease in precipitation towards their interiors. Further, the mountain barriers alter the ideal precipitation pattern that one would expect from the global wind systems. Windward mountain slopes receive abundant precipitation, while leeward slopes and adjacent low lands fall in rain-shadow.

On the basis of the total amount of annual precipitation, major precipitation regimes of the world may be identified in Fig. 11.8.

The equatorial belt, the windward slopes of the mountains along the western coasts in the cool temperate zone and the coastal areas of the monsoon lands, receive heavy precipitation of over 200 centimetres per annum.

Areas adjacent to the high precipitation regime receive moderate rainfall varying from 100 to 200 centimetres per annum. The coastal areas in the warm temperate zone also receive moderate amount of rainfall.

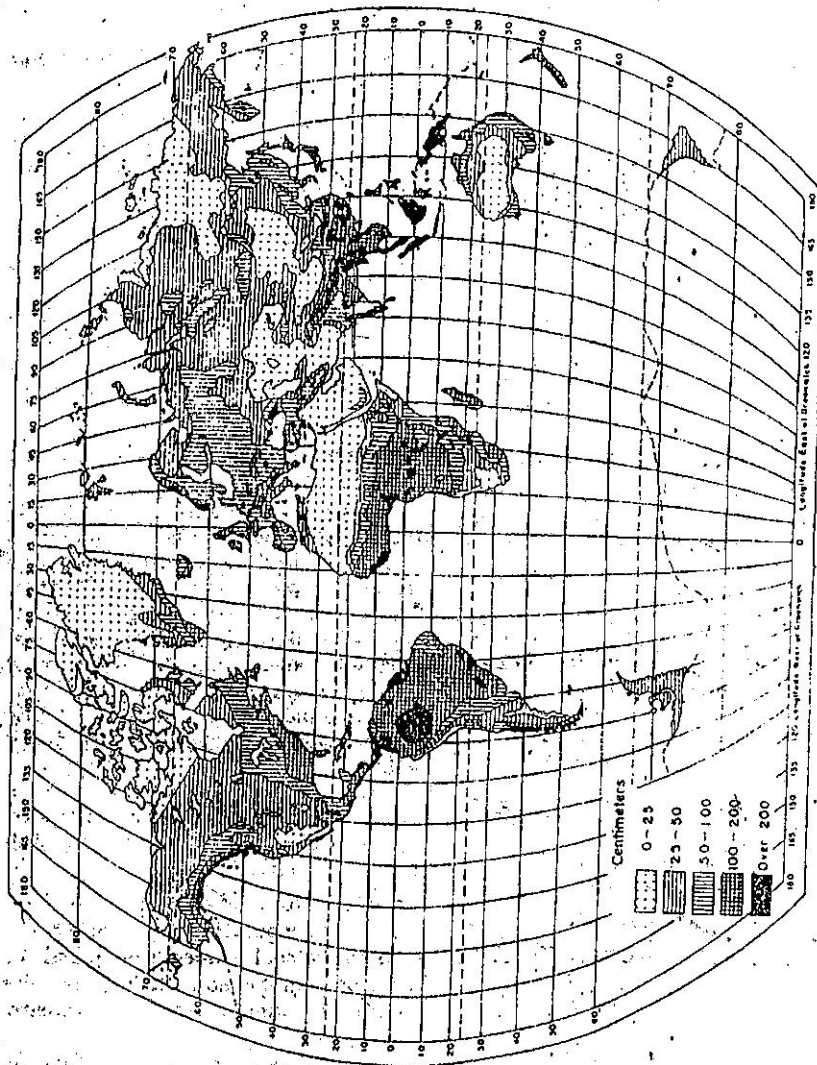


Fig. 13.8 World distribution of precipitation

The central parts of the tropical land and the eastern and interior parts of the temperate lands receive inadequate precipitation varying between 50 to 100 centimetres per annum.

Areas lying in the rain-shadows, the interior of the continents and high latitudes receive low precipitation of less than 50 centimetres per annum. The western margins of the continents in the tropical lands, and the arid deserts come under this category.

Seasonal distribution of rainfall provides an important aspect to judge the effectiveness of precipitation. In some regions, precipitation is distributed evenly throughout the year such as in the equatorial belt and the western parts of cool temperate regions. On contrary, some

of the regions such as monsoon lands, and the Mediterranean regions experience seasonal rainfall. For example in our country, too much of rain in one season is often followed by long dry season. This leads to the wastage of rain-water in one season and an appalling scarcity in the other.

Even if the precipitation is scanty but concentrates in a short growing season, as in high latitudes, its maximum utilization is possible.

Precipitation even in the form of fog, mist or dew in certain parts has an appreciable effect on vegetation. The dense fog nourishes vegetation in the Kalahari Desert, and dew and mist in winter nourishes wheat crops in parts of Central India.

EXERCISES

Review Questions

1. Answer the following questions:

- (i) What is humidity?
- (ii) What are the factors controlling the amount and rate of evaporation?
- (iii) How does condensation take place?
- (iv) What are the different forms of condensation?
- (v) How clouds are formed?
- (vi) What are the different types of clouds?

2. Distinguish between:

- (i) Fog and mist; (ii) dew and dew point; (iii) absolute and relative humidity, and (iv) rainfall and snow-fall.

3. Write short notes on:

- (i) Frost, (ii) Adiabatic temperature changes, (iii) Orographic precipitation, (iv) Convictional precipitation, (v) Hail, (vi) Rain-shadow areas.

4. Discuss the salient features of the world distribution of rainfall and the associated controlling factors.

5. Give a single term for each of the following :

- (i) The amount of actual water-vapour present in per unit volume of air.
- (ii) The air that contains moisture to its full capacity.
- (iii) The process of change of state from gaseous to liquid or solid forms of water.
- (iv) Falling of the frozen rain drops and re-frozen melted snow on the earth's surface.
- (v) Rainfall associated with the convergence of warm and cold air masses.

Finding Out

6. Maintain a record of climatic phenomena such as duststorm, thunderstorm, thick fog, dew, frost and heavy downpour in your locality. At the end of the year, you would be in a position to generalize your data—the frequency and intensity of each type of phenomenon. Correlate your findings with the climate of your region.

Cartographic Work

7. Study carefully the world map showing distribution of rainfall and answer the following questions :

- (i) Why the amount of precipitation is meagre in the northern parts of Canada, Greenland and Siberia?
- (ii) Why do the Central America, Northern Africa and Southern China receive different amounts of rainfall while they are located in the same latitudes?

Further Readings

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CHAPTER 14

Classification of Climates

WE have so far examined the spatial and seasonal variations of the major elements of weather and climate, such as temperature, pressure, winds, humidity, and precipitation. Weather is the sum total of the atmospheric conditions in a place or in an area in terms of these elements at a particular instant. Thus, it refers to specific atmospheric conditions. Climate, on the other hand, indicates a generalized and composite picture of the average weather conditions and prominent departures from the average spread over a long period, for a given larger area. The combined effects of the variations of the major climatic elements in different parts of the world and also the varied nature of the earth's surface give every location a distinctive climate. Hence, the number of different climates is extremely large. Such a variety poses problem in providing simple explanations. It is, therefore, essential to classify the different climates into few major groups having certain common important characteristics. In other words, it means systematic arrangements of information in a simplified and generalised manner. This would not only help in comprehension but would also facilitate analysis and explanations.

Several attempts have been made to classify the climates of the world to describe and delimit the major types of

climates in quantitative terms. It should, however, be remembered that no single classification can be perfect because climate stands for the generalized and composite weather conditions. The value of any particular classification is determined by its intended use. A system designed for one purpose may not necessarily be applicable to another.

Probably the first attempt to classify the world climates was made by the ancient Greeks. On the basis of temperature, they divided the earth into (i) *Torrid* (tropical); (ii) *Temperate* (mid-latitude); and (iii) *Frigid* (polar) zones. The boundaries of these zones were the four astronomically important parallels. The low latitudes bounded by the Tropic of Cancer and the Tropic of Capricorn having high temperature throughout the year were called the winterless *torrid* or tropical region. Bounded between the Tropic of Cancer and the Arctic Circle in the Northern Hemisphere, and the Tropic of Capricorn and the Antarctic Circle in the Southern Hemisphere, were the two zones of *temperate* climate. These zones experienced marked seasonal contrast in temperature. Regions lying beyond the Arctic and the Antarctic circles, experienced low temperature throughout the year and hence, were designated as *frigid* zone.

Since that time, many classifications of climate have been devised. However,

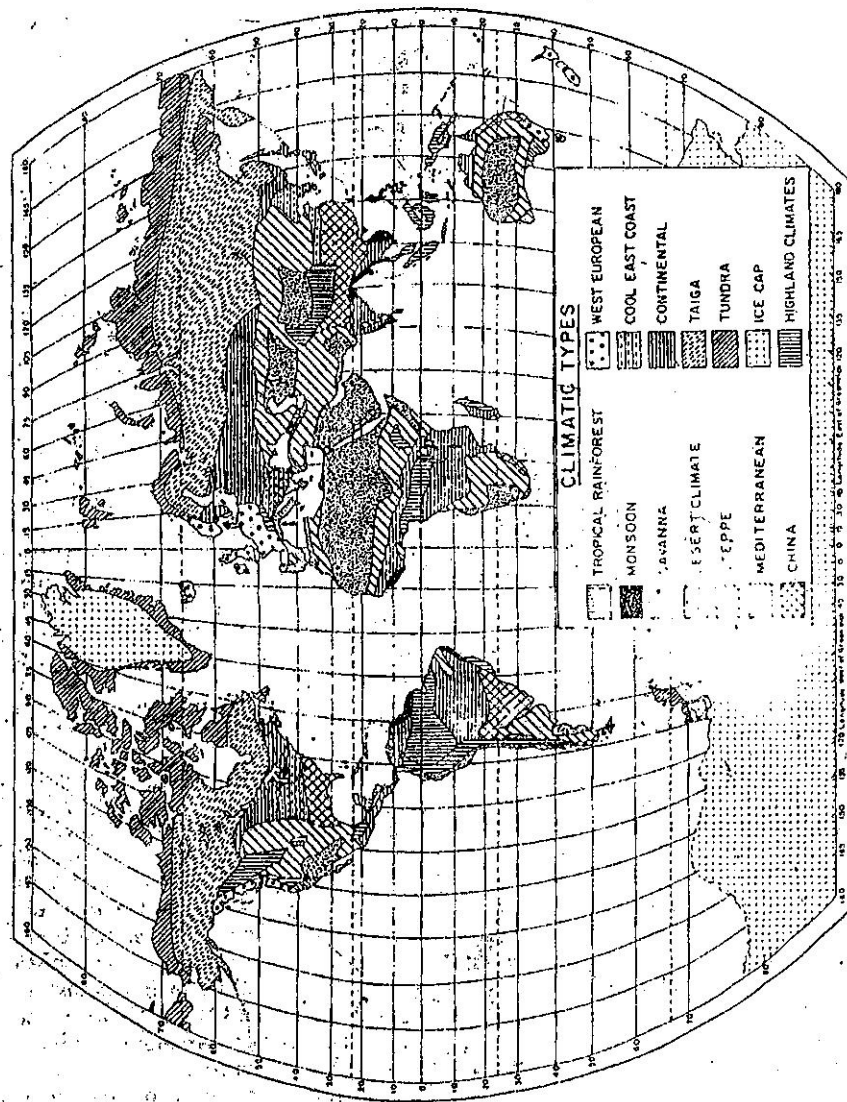


FIG. 14.1 Distribution of major climatic types

among the modern classification schemes, two have gained wider acceptance and popularity. These schemes are those of W. Köppen and C.W. Thornthwaite. These are quantitative in expression as they use numerical values for defining the boundaries of the climatic groups and types. Here, we will describe main types of climates based on the classification scheme of W. Köppen, which has been the most popular system used nowadays.

Köppen's Classification

Köppen's classification is based upon temperature, precipitation and their seasonal characteristics. He aimed at providing a quantitative scheme which would relate climate to vegetation in an objective manner since he believed that the distribution of natural vegetation was the best expression of the totality of climate. Definite numerical values of temperature and precipitation have been established for delimiting the boundaries of different climatic types. However, these boundaries are not fixed and they should be regarded as a broad transition zone. Broadly, five principal groups have been recognized. Each group has been designated by a capital letter. These major groups are further sub-divided into a number of climatic types on the basis of temperature and precipitation differences.

Besides these five groups, the climate of highlands has been also included in this book as a separate category because altitudinal zonation of vegetation on the mountains also reveal similar pattern as one notices while going from the low latitudes to high latitudes.

Climatic Groups	Climatic Types
A. Humid tropical climates (No cool season)	(i) Tropical rainforest (ii) Savanna (iii) Monsoon

B. Dry climates (Climates where evaporation exceeds precipitation and there is constant water deficiency).	(iv) Desert climate (v) Steppe
C. Humid middle latitude climates (Mild winters)	(vi) Mediterranean (vii) China (viii) West European climate
D. Humid middle latitude climates (Severe winter)	(ix) Taiga (x) Cool east-coast (xi) The continental
E. Polar climate (No warm season)	(xii) Tundra (xiii) Ice-cap climate
F. The climate of highlands	

A. Humid Tropical Climate

The tropics having this kind of climate occupy almost half of the earth's surface, over 20 per cent of the land and 40 per cent of the ocean surface. This climatic group is bounded by the mean annual isotherm of 20°C. The hot deserts of North Africa and Arabia lying within this area are excluded from this group because of their extreme aridity. In this belt, temperature is more or less uniform. Principal climatic types within this group are identified basically on the basis of their seasonal distribution of rainfall.

(i) The Tropical Rainforest or Equatorial Climate

This climate is found in the belt extending from equator to 10°N. and S. latitudes. Along the windward margin of the continents, this climate may extend upto 20° North and South latitudes. The Amazon basin, the Congo basin and the south-east Asian Islands have this kind of climate.

This climate has uniformly high temperature throughout the year, the annual average being about 27°C. The daily range of temperature is in between

10°C and 25°C. The annual range is, however, less than 5°C. Rainfall is heavy and is distributed throughout the year. The annual average rainfall is about 250 cm. The constantly high temperature and all the year round rainfall help to produce the most luxuriant vegetation in the region, which is known as the *tropical rainforest* or *selva*.

(ii) *The Savanna Climate*

This climatic type is bounded by tropical rainforest climate toward the equator and by dry climates towards the poles. Areas having a savanna climate are the Sudan and Veld Plateau of Africa, the tropical grasslands of northern Australia, the Llanos of the Guiana highlands of South America and the Campos of Brazil. It represents a transitional zone which gets convectional rainfall during the summer, whereas during rest of the year it remains dry under the dominating influence of the trade winds.

Temperature is high throughout the year, the annual average temperature being about 23°C. The annual range of temperature is 5° to 6°C. The annual rainfall is about 160 cm. Wet summers alternate with dry winters. Floods and droughts are quite common. Duration of the rainy season and the average amount of annual rainfall decreases with the increasing distance from the equator. Similarly, annual range of temperature also increases away from the equator. Here the tropical rainforest gives way to the *savanna*, a tropical grassland with scattered deciduous trees.

(iii) *The Monsoon Climate*

The monsoon climate is found in India, south-east Africa, northern Australia, the Guinea Coast of West Africa and the Pacific Coast of Columbia. The monsoon

climate is characterized by seasonal reversal of wind direction associated with alternating periods of rainfall and drought. During the summer season, humid unstable air moves from the oceans towards the land. Conditions are, therefore, conducive to rainfall. In winter, a dry wind originating over the land, blows towards the seas. The monsoonal circulation system having reversal of wind direction develops in response to the differences in annual temperature variations between continents and oceans. During summer, the intense heating of Central Asia produces an area of very low pressure, whereas in the Southern Hemisphere there exists the sub-tropical high pressure over the oceans. The south-east trades flow from the high pressure to the low pressure area and are deflected to the right and reach India and south-east Asia as on-shore south and south-westerly winds. These winds are laden with moisture and, therefore, cause heavy rainfall in these parts of the Asian Continent.

During winter, the excessive cooling in Central Asia intensifies the high pressure belt and the off-shore north-east trades blow over south-east Asia. Due to the presence of the Himalaya, these cold winds are prevented from descending into the Indian Peninsula. Temperatures are low during this season.

B. *The Dry Climates*

The dry climates have been sub-divided into the arid or desert type, and the semi-arid or steppe type. These two climatic sub-divisions have many features in common. Their differences are primarily a matter of degree.

(iv) *The Desert Climate*

The chief feature of any desert climate is the scarcity of water. This results where

evaporation exceeds precipitation. Aridity or dryness is not simply a matter of low precipitation, but of the 'effective precipitation'. For example, 25 cm of precipitation may be sufficient to support the forest cover in Scandinavia where evaporation is less in the cool moist air. But the same amount of rainfall in Iran supports only a sparse vegetative cover because evaporation is very high in hot dry air. Hence, no specific amount of precipitation can serve as a universal boundary for dry climates.

In Koeppen's classification, three variables have been used in the formula to establish the boundary between dry and humid climates. These variables are (i) average annual temperature; (ii) average annual precipitation; and (iii) seasonal distribution of precipitation. With the increase in temperature, potential evaporation (evapotranspiration) also increases.

The arid deserts lie in the low-latitudes close to the Tropic of Cancer and the Tropic of Capricorn. The Sahara, the Arabia, the Thar, south-western USA, south-western Africa and Central Australia have this type of climate. This climate is dominated by the subsidence of air masses and marked stability of the sub-tropical anticyclones and hence, nearly rainless. Precipitation is not only scanty but is also very erratic. The cloudless sky and low humidity allow a great amount of solar radiation to reach the ground during the day and permit rapid terrestrial radiation at night. Consequently, low-latitude deserts in the interior of the continents have the greatest daily ranges of temperature on the earth, which is more than 15°C. Average annual temperature is about 38°C.

Tropical deserts located along the west coast of continents reveal marked influence

of cold ocean currents on their climates. For example, Atacama in Peru and Chile and the Namib in south-west Africa have lower annual means as well as annual and diurnal ranges of temperature compared to other stations located at similar latitudes, but in other parts. However, these areas receive the lowest annual rainfall totals in the world despite their location adjacent to the oceans. In fact, the aridity in this part is intensified because of the cold off-shore waters which chill the air and further stabilize it.

(v) *The Steppe*

Unlike the low-latitude deserts, the steppes are not controlled by the subsiding air masses of the sub-tropical anticyclones. Instead, these are dry lands principally because of their position in the deep interiors of large land masses away from the oceanic influences. In addition, presence of mountain barriers across the paths of the prevailing winds further restrict maritime influences. The middle latitude deserts having steppe climates are, therefore, most widespread in North America and Eurasia.

This climatic type is characterized by meagre and unreliable precipitation like the tropical deserts. However, annual means (21°C) as well as annual range of temperatures (13°C) are comparatively lower. The annual rainfall is 30 cm. Steppes located on the poleward side of the deserts receive maximum rainfall during the cool season, while those located towards the equator receive it during the warm season.

C. *Humid Mid-Latitude Climates*

This climatic group is sub-divided into the Mediterranean, China and West European climatic types. The coldest month is below 18°C, but temperature

never goes below -3°C . The warmest month records temperature over 10°C .

(vi) *The Mediterranean Climate*

This climate is found along the west coasts of continents between 30° and 45° latitudes. It is bounded by the arid steppe on the equatorward side and the Marine West European climate on the poleward side. Areas around the Mediterranean Sea, Central California, Central Chile, southern part of South Africa and south-eastern and south-western parts of Australia experience this climate.

As there is seasonal shift of pressure belts with the annual movements of the sun, these areas come under the influence of sub-tropical high-pressure conditions during summer, and cyclonic low-pressure conditions during winter. Summers are, therefore, warm and dry, temperature being in between 20°C and 27°C . Winters are mild with temperature ranging between 4°C and 10°C . The annual range of temperature is about 10°C to 17°C . Rainfall is moderate and varies between 40 and 60 centimetres. Most of it occurs in the winter season.

(vii) *The Humid Sub-Tropical Climate or the China Type*

The humid sub-tropical climate is found along the eastern coasts of continents between 25° and 45° latitudes. It occurs in the south-eastern United States, Uruguay, Argentina, southern Brazil, eastern China, southern Japan and eastern coastal belt of Australia.

Summers are hot and humid. Winters are mild. The average annual temperature is 20°C and the average annual range of temperature is about 17°C . Yearly precipitation totals are usually more than 100 centimetres. It is well distributed throughout the year. These areas

experience dreaded hurricanes and typhoons, mostly in the late summer and autumn.

(viii) *The Marine West European Climate*

This climate is found along the western coasts of continents from about 40° and 65° North and South latitudes. This climatic region is dominated by the on-shore flow of oceanic air. Under the influence of maritime air masses, these areas experience mild winters, cool summers and ample amount of rainfall throughout the year. This climate is found most widely in Europe, where in the absence of any mountain barrier running north-south, the movement of cool maritime air is not restricted. In North and South Americas, this climate is found only in narrow belt along the coast, because of the presence of mountain barriers. Besides these areas, New Zealand and south-eastern tip of Australia also experience this climate.

Weather remains highly variable and unpredictable throughout the year under the influence of cyclonic low pressure system. The average annual temperature is 10°C . Total annual rainfall is about 140 centimetres. The winters are rainier than the summers.

D. Humid Mid-Latitude Climates

Humid mid-latitude climates having low temperatures have been sub-divided into the taiga climate, the cool east coast, and the continental climates.

(ix) *The Taiga Climate*

This climatic type has been named after the coniferous forest cover found in the region. This climatic region covers broad expanses from western Alaska to Newfoundland in North America, and from Norway to the Kamchatka Peninsula in Eurasia.

The climate is dominated by continental, polar air masses. The summers are short and the temperature varies between 10°C and 15°C . The winters are long and very cold. Minimum temperature may be as low as -50°C (recorded at Verkhoyansk in January). The precipitation is low and is concentrated in warmer months. Despite its small amount, it is sufficient for tree growth because evaporation is less. The vegetation associated with this climatic type is the soft-wood coniferous forest.

(x) *The Cool East Coast Climate*

This climate is found in areas located along the north-eastern coast of the United States, northern China, Japan, Korea and lower Danube Plains.

The summers are long, hot and humid under the influence of tropical maritime air masses. Average summer temperature is 25°C . The winters are cold and the average winter temperature ranges between -4°C and 0°C . Precipitation is variable. Summer rainfall is characteristic and is convectional in nature. In winter, precipitation is usually less than in summer, and falls mostly in the form of snow.

(xi) *The Continental Climate*

This climatic region is situated in the interior parts of the big continents between the Taiga and the mid-latitude deserts. In Eurasia, it spreads from Poland and Baltic States to the Central Russian Plain. Beyond the Ural mountains, the belt is narrow and runs along the 55° parallel. In North America this climate is found in the northern states of the United States and the southern parts of the central states of Canada.

Temperature is usually higher than those of the Taiga type climate, but is lower than those of the cool east coast

climate. Summers are short and warm, temperature being in between 10°C and 21°C . Winter is long. Temperature goes down below freezing point. Precipitation is variable and comes mostly in summer as rainfall. Winter precipitation is in the form of snow.

E. The Polar Climates

Polar climates are those in which the mean temperature of the warmest month is below 10°C . These are thus characterized by the absence of a warm period and by long cold conditions. This climatic group has been sub-divided into two types — The Tundra Climate in which warmest month has a temperature above freezing point but is less than 10°C ; and The Ice-cap Climate in which the warmest month has temperature below 0°C .

(xii) *The Tundra Climate*

It is found almost exclusively in the Northern Hemisphere occupying the coastal fringes of the Arctic Ocean and many Arctic Islands and the ice-free shores of Iceland and Greenland.

Winters are severe but summers are cool. Annual temperature ranges are high. Precipitation is small. Temperature of the warmest month does rise above 0°C , but never above 10°C . As such, the ground may be free from snow, but for a short period. The 10°C summer isotherm thus marks the equatorward limit of the tundra as well as the poleward limit of tree growth. Only sparse vegetation is possible which comprises grasses, mosses and lichens.

(xiii) *The Ice-cap Climate*

The Ice-cap climate does not have a single monthly mean above 0°C . Consequently, the growth of vegetation is prohibited and it is a region of permanent ice and snow.

F. Climate of the Highlands

In mountainous regions, altitude and aspect play important roles in controlling temperature and precipitation. On high mountains the effect of high altitude is almost the same as that of high latitudes on the globe. This may be revealed by altitudinal zonation of vegetation from foot of the mountains to their tops. High insolation, low temperature, low air pressure, large diurnal ranges of temperature and relatively large amount of precipitation at higher altitudes are common. This type of climate is found in the Alps, the Himalayas, the Tibetan Plateau, the Rockies and the Andes.

Climate and Man

Since climate refers to the atmospheric conditions of the earth over a long period of time, it is one of the most important aspects of the natural environment. It represents the living atmosphere, with which hydrosphere, lithosphere and

biosphere constitute the natural environment. Climate affects and is also affected by the processes and conditions of the other three components, i.e., hydrosphere, lithosphere, and biosphere.

Climate sets limits to the distribution of different kinds of plant and animal lives. It has, therefore, a great significance for man. It influences human activities both directly and indirectly. Agriculture, irrigation, forestry, construction of houses, land use, transportation and other economic activities are greatly influenced by the climatic conditions. Indiscriminate cutting of trees by man in several parts of the world has led to decrease in the amount of precipitation and hence more frequent famine conditions. Similarly, increase in the burning of fossil fuels during past several decades has caused increase in the amount of carbon dioxide in the atmosphere. This has raised the temperature of the atmosphere to some extent.

EXERCISES

Review Questions

1. Answer the following questions:

- (i) Distinguish between weather and climate.
- (ii) Which are the two well-known climatic classifications?
- (iii) What climate data are used in Koeppen's scheme of classifying climates?
- (iv) Which type of climate is known for the minimum range of annual temperatures?
- (v) Why is the amount of precipitation that defines the humid-dry boundary variable?
- (vi) What is the significance of the 10°C summer isotherm?
- (vii) What are the characteristics of the Savanna climate?

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2. Write short notes on:

(i) Major temperature zones of the world; (ii) The Taiga Climate, (iii) The Tropical Rainforests, (iv) The Climate of the Highlands; and (v) Climate and Man.

3. Compare the low-latitude desert climate with the steppe.
4. Discuss the main characteristics of the monsoon climate.
5. Explain why the marine west European climate is found only in a narrow belt along the coast in North and South Americas?
6. Listed below are some important characteristics of a few climatic types. Name the climatic types of which they refer to:

- (i) High temperature throughout the year, wet summers and dry winters.
- (ii) Greatest daily ranges of temperature on the earth.
- (iii) Reversal in wind direction with change of season.
- (iv) Constantly high temperature and heavy precipitation throughout the year.
- (v) Warm and dry summer, mild winter, moderate rainfall mostly in winter.
- (vi) Short summer temperature ranging between 10°C to 15°C; long and very cold winters, low precipitation, mostly in warmer months.
- (vii) Severe winter, cool summer with temperature not rising above 10°C.

Finding Out

7. "Distribution of natural vegetation is the best expression of the totality of climate." Collect information with regard to climatic data and photographs, pictures, depicting natural vegetation for each climatic type in support of this statement.

Cartographic Work

8. Refer to Appendix II given in this book. Prepare temperature and rainfall graphs for each climatic type.

Further Readings

- Critchfield, H. *General Climatology*, New York: Prentice Hall, 1961.
 Koeppen, C.E. and De Long, G.C. *Weather and Climate*, New York: McGraw Hill, 1958.
 Lutgens, F.K. and Tarbuck, E.J. *The Atmosphere*, New Jersey: Prentice Hall, 1979.

1. The first of these is the fact that the Chinese people are not a homogeneous race. They are divided into many different groups, each with its own language, customs, and traditions. This makes it difficult to speak of a single Chinese culture or identity.

2. The second is the fact that the Chinese people have a long history of being ruled by foreign powers. This has led to a sense of national humiliation and a desire for independence. This desire has been a major factor in the development of the Chinese Revolution.

3. The third is the fact that the Chinese people are a very young nation. They have only been a unified state for a few decades. This makes it difficult to speak of a single Chinese culture or identity.

4. The fourth is the fact that the Chinese people are a very diverse nation. They have many different languages, customs, and traditions. This makes it difficult to speak of a single Chinese culture or identity.

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10. The tenth is the fact that the Chinese people are a very diverse nation. They have many different languages, customs, and traditions. This makes it difficult to speak of a single Chinese culture or identity.

The Hydrosphere

CHAPTER 15

The Profile of the Ocean Floor

THE FLOORS of the oceans are not plain as believed earlier. They are rugged and complex with world's longest mountain ranges, deepest trenches and largest plains. The development of the Sonic depth recorder has made it possible to measure depth for mapping the ocean floor indirectly with the help of sound waves. The echo or the sound returning after striking the ocean bottom forms the basis of this device. The data reveal many complex and varied features which rival anything about relief features on the land.

In general, the ocean floor can be divided into four major divisions: (i) The continental shelf, (ii) The continental slope, (iii) The continental rise, and (iv) The abyssal plain. Besides, there are many associated features including ridges, hills, seamounts, guyots, trenches, canyons, deeps and fracture zones. Numerous island arcs, atolls, coral reefs, submerged volcanoes, and sea-scrapes add to the variety of submarine features. As the trenches and ridges abound on the ocean floor, the ridge and basin topography is the characteristic of the ocean bottom. The transverse ridges sub-divide the depressions into a series of basins which are separated from each other. The great variety of relief is largely due to the interaction of tectonic, volcanic, erosional and depositional processes. At greater depths, tectonic and volcanic phenomena are more significant processes.

Continental Shelf

The Continental Shelf is a gentle seaward sloping surface extending from the coasts towards the open sea. The shelf is generally formed by the drowning of part of a continent with a relative rise in sea level or marine deposition beneath the water. The seaward edge of the continental shelf is usually 150-200 metres deep. The shelf varies in its width. It is almost absent of the eastern Pacific, especially in South America. Along other coasts, it is broad for example the eastern coast of the United States, it is 120 kilometres wide. Along the eastern coast of India, also a wide strip of Continental Shelf is noted. However, the average width of Continental Shelf is about 70 kilometres and mean slope is less than one degree. The angle of slope is usually the least where the shelf is widest. In all, about 7.5 per cent of the total area of the oceans is covered by the continental shelves.

The continental shelves are mostly covered by sediments derived from rocks on land. Some of them are underlaid by sedimentary strata while others by the igneous and metamorphic strata. There are various types of shelves including glaciated shelf, coral reef shelf, shelf of a large river, shelf with dendritic valleys, and the shelf along young mountain ranges. Old beaches and moraines can both be identified on the shelves.

The shelves of the world are of great use

to man. Marine food comes almost entirely from them. They provide the richest fishing grounds. They are also potential mining sites for economic minerals. About 20 per cent of the world production of petroleum and gas comes from shelves. They are also large stores of sand and gravel.

Continental Slope

At the edge of the continental shelf, the seaward slope becomes considerably steep, the angle of slope varying from 2° to 5 degrees. This steep slope, which descends to a depth of about 2,000 fathoms or about 3,660 metres from the mean sea level is known as continental slope. The continental slope joins the shelf to the deep ocean floor.

The continental blocks are supposed to end at the site of the continental slope. The continental slope along many coasts of the world is furrowed by deep canyon-like trenches terminating as fan-shaped deposits at the base. There are five types of slopes: (i) fairly steep with the surface dissected by canyons; (ii) gentle slope with elongated hills and basins; (iii) faulted slopes; (iv) slopes with terraces; and (v) slopes with seamounts.

Continental Rise

Where the continental slope ends, the gently sloping continental rise begins. The continental rise has an average slope of between 0.5° to 1° and its general relief is low. With increasing depth the continental rise becomes virtually flat and it merges with the abyssal plain.

Abyssal Plains

Beyond the continental rise lie the deep sea plains known as the abyssal plains or abyssal floors. They are areas of deep

ocean floor found at a depth of 3,000 to 6,000 metres. They occupy about 40 per cent of the ocean floor and are present in all major oceans and several seas of the world. They are uniquely flat with a gradient of less than 1:100. They are bounded by the hills on the seaward side. The abyssal plains are covered by sediments both of terrigenous and shallow water origins. In general, abyssal plains are more common where land-derived sediments are in great supply. The irregular topography is buried forming relatively flat areas due to the large supply of sediments.

Submarine Ridges

Submarine ridges are mountain ranges a few hundred kilometres wide and hundreds and often thousands of kilometres in length on the floors of oceans. These submarine ridges of high relief, form the longest mountain system on the earth. The total length of submarine ridge system is more than 75,000 kilometres. A large number of ridges are placed centrally in the oceans. They meet or intersect at several places. These ridges are either broad like a plateau, or gently sloping or steep-sided narrow mountains. Their summits may rise above sea level forming islands. The submarine ridges have been formed by various processes. The world-wide oceanic ridge system provides evidence of global tectonics.

Abyssal Hills

The deep sea floor also contains thousands of isolated abyssal hills, seamounts and guyots. A submarine mountain or peak rising more than 1,000 metres above the ocean floor is known as a seamount. Flat-topped seamounts are known as guyots. All these features are of volcanic origin. Seamounts and guyots are very common in

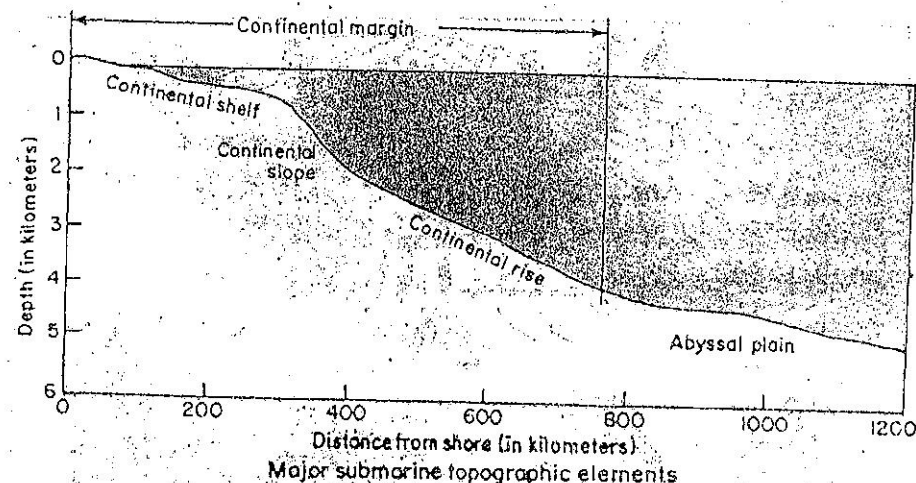


FIG. 15.1 Major submarine topographic elements

the Pacific Ocean. Oceanographers believe that there are 10,000 seamounts and guyots in the Pacific Ocean alone.

Submarine Trenches or Deep

These are the deepest parts of the oceans with their bottoms far below the average level of the ocean floors. A long, narrow and steep-sided depression on the ocean bottom is called a Trench. They are usually 5,500 metres in depth and lie along the fringes of the deep-sea plain. They are believed to have resulted from down faulting or down folding of the earth's crust and are, therefore, of tectonic origin. The trenches generally run parallel to the bordering fold mountains or the island chains. Although trenches are found in all major oceans, they are most common in the Pacific Ocean. Trenches form an almost continuous ring along the eastern and western margins of the Pacific. Among the trenches of the Pacific Ocean, the Mariana off the Guam Islands is the deepest. While the average depth of the

oceans is four kilometres, it is as much as 11 kilometres deep. If the Mt. Everest were to be submerged in this trench, its peak would still remain two kilometres below the sea level.

Submarine Canyons

Submarine canyons are deep gorges on the ocean floor. They are strikingly deep valleys with steep slopes that form long, concave profiles. They occur around all the coasts of the world and are mainly restricted to the continental shelf, slope and rise. Broadly, there are three types of submarine canyons: (i) small gorges which begin at the edge of the continental shelf and extend down the slope to very great depths e.g., Oceanographer Canyons near New England; (ii) those which begin at the mouth of a river and extend over the shelf, such as the Zaire, the Mississippi, and the Indus Canyons, and (iii) those which have a dendritic appearance and are deeply cut into the edge of the shelf and the slope, like the

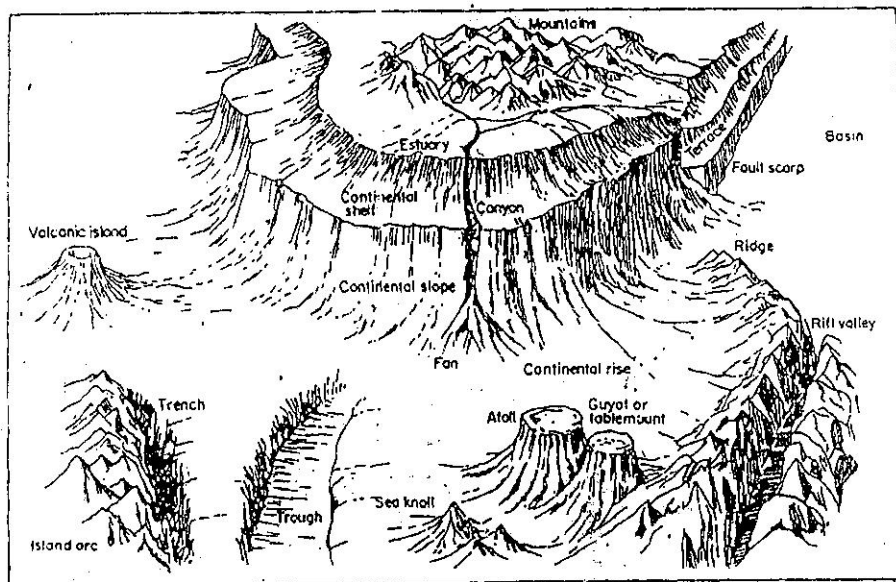


FIG. 15.2 Major submarine topographic features

Canyons off the coast of southern California. Many canyons in the oceans have their heads near the mouths of rivers. Hudson Canyon is the best known canyon in the world. It begins near the mouth of the Hudson river and extends into the Atlantic Ocean. Some of the canyons are comparable in size to the Grand Canyon. The largest canyons in the world occur in the Bering Sea off Alaska. They are the Bering, Pribilof and Zhemchug canyons. The Bering is about 400 km long and has a volume of about 4,300 cubic km. The Zhemchug has a depth of 2,600 metres and a volume of 8,500 cubic km. Some canyons also terminate in fan-shaped cones or in deltas on the sea floor.

Bank, Shoal and Reef

Bank, shoal and reef are the marine

features which are formed through the processes of erosion, deposition and biological activity. These features are produced upon other features which are primarily of diastrophic origin. They are, therefore, located on upper parts of elevations.

A bank is more or less flat-topped elevation located in the continental margins. The depth of water over a bank is relatively small but is adequate for navigation. The Dogger Bank in the North Sea and the Grand Bank in the north-western Atlantic off Newfoundland, are famous examples. At places, as in the Grand Bank, the banks are formed by many hills of the outer shelf rising nearly to sea level. During the Pleistocene Ice age, when there was a fall in the sea level, the surfaces of these banks were glacially

eroded. The Georg's Bank off the eastern coast of the U.S.A. is an example of this type of bank. On the other hand, the Dogger Bank constitutes the remains of a glacial moraine. The offshore banks are almost everywhere modified by tidal streams. The banks are the sites of some of the most productive oceanic fisheries of the world.

A shoal is a detached elevation with shallow depths. The shoal is not composed of a rock or coral. At many places, shoals are associated with banks. In the Dogger Bank there are shoals which are about 18 metres high above their surroundings and only about 20 metres below the water surface at their crests. That is why shoals are dangerous for navigation.

A reef is predominantly organic deposit made by living or dead organisms that forms a mound or a rocky elevation like a ridge. The reefs formed by coral organisms are most characteristic of the Pacific Ocean where they are associated with seamounts and guyots. The largest reef in the world is found off the Queensland coast of Australia. Reefs are generally dangerous to navigation because they may extend above the surface.

The study of the morphology of the oceans is important because the relief controls the nature, character and the motion of sea water. The oceanic movement in the form of currents in turn causes many variations which are important to the character of marine fauna and flora. The bottom relief of oceans also influences navigation, fishing and other important activities of man. Given below are the features of the bottom relief of different oceans.

The Pacific Ocean

This ocean is the largest of all the water bodies. Together with its associated seas, it

covers about one-third of the earth's surface and exceeds the total land area of the world in size. Its shape is roughly triangular with its apex in the north at the Bering Strait. It is bounded on the west by the continents of Asia and Australia along with a chain of intermediate islands, on the east by North and South Americas and on the south by Antarctica.

The Pacific is the deepest of all oceans. The major portion of the basin has an average depth of about 7,300 metres. Many marginal seas, bays and gulfs occur along its boundaries.

This vast ocean is dotted with more than 20,000 islands, though their total area may be small. The islands situated close to the continent are continental islands. The islands appearing in the mid-ocean are coral and volcanic in origin.

The ocean floor of the Pacific Ocean is fairly uniform with broad rises and depressions. Study the map of the Pacific Ocean basin and locate various submarine features on it.

The Northern Pacific is the deepest part of the ocean. The average depth of this part ranges between 5,000-6,000 metres. This part has a large number of deeps, trenches and islands areas. Aleutian, Kurile, Japan and Bonin are some well-known trenches of this part, ranging in depth from 7,000-10,000 metres. Most of the deeps are found bordering the island areas. There are also a large number of seamounts, guyots and parallel, and arcuate island chains in the central part.

The south-west portion of the Pacific is marked by a variety of islands, marginal seas, continental shelf and submarine trenches. The Mindanao trench is more than 10,000 metres deep. The average depth of this part is about 4,000 metres. The south-east Pacific has broad submarine ridges and plateaus. This part

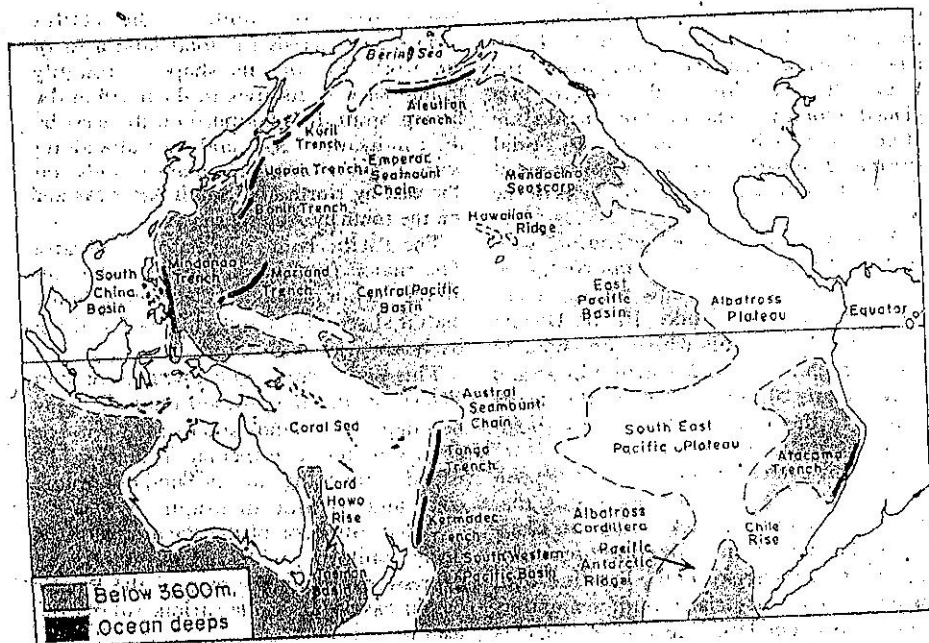


FIG. 15.3 The profile of the Pacific Ocean basin

of the Pacific is conspicuous by the absence of marginal seas. The Tonga and Atacama trenches in this part are about 9,000 and 8,000 metres deep, respectively.

The Atlantic Ocean

It is roughly half the size of the Pacific Ocean and covers about one-sixth of the earth's total area. It resembles the letter 'S' in shape. On the west, it is bounded by the Americas and on the east by Europe and Africa. In the south, it is open and may be considered to extend upto the Continent of Antarctica. In the north, however, Greenland, Iceland and other smaller islands appear to enclose it.

The continental shelf occurs all around the Atlantic Ocean, but it varies in width. Off the coast of Africa, it is 80-160

kilometres wide but off the coast of north-east America, north-west Europe, it is 250-400 kilometres wide.

The Atlantic Ocean has numerous marginal seas on both sides, especially in its northern part. Most of the marginal seas are located on the shelves. Hudson Bay, the Baltic Sea, the North Sea, are located on the shelves.

The most striking feature of the Atlantic Ocean is the presence of the mid-Atlantic Ridge. It extends from the north to the south paralleling the 'S' shape of the ocean itself. It divides the Atlantic into two deeper basins on either side. The ridge is about 14,000 km long and about 4,000 metres high. The ridge is a broad fracture and a stretched feature. The slopes on both sides of the ridge are very gentle throughout.

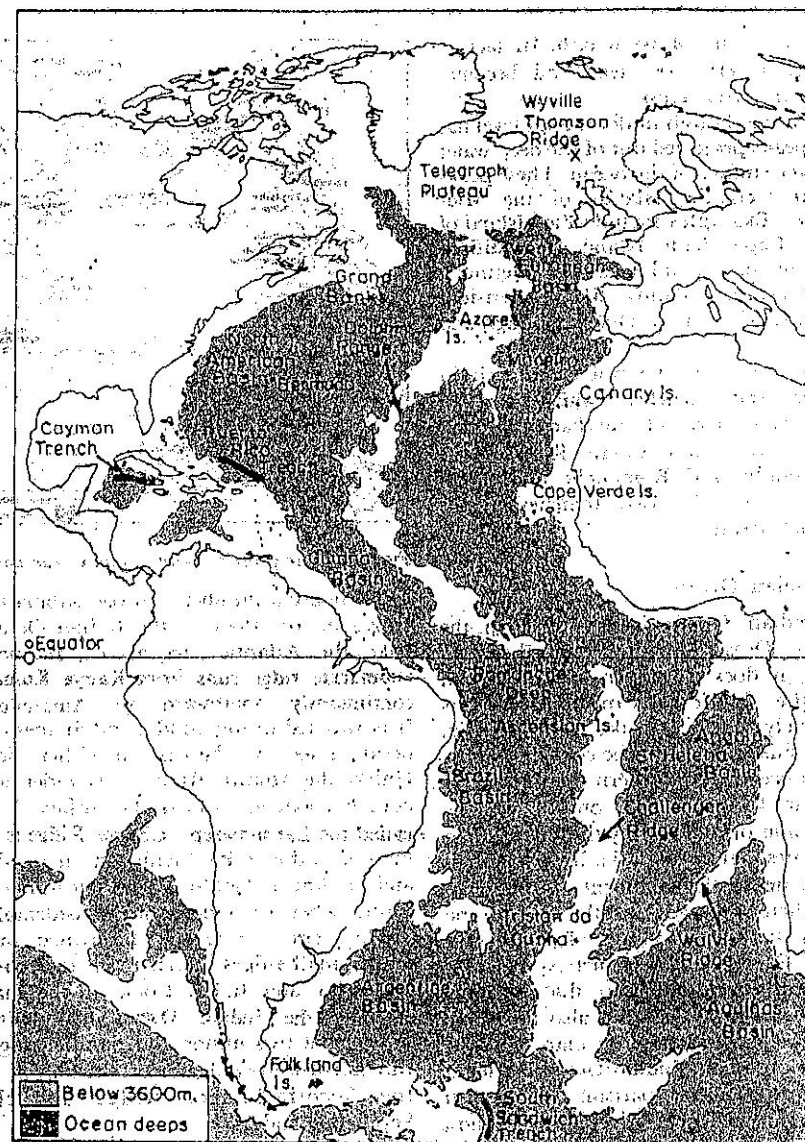


FIG. 15.4 The profile of the Atlantic Ocean basin.

the greater part of its length. In fact, it rises as a series of steps and becomes rugged near the crest.

The ridge though under the sea level has many peaks projected out of the deep water above the surface of the ocean. These peaks are, in fact, the islands of the Mid-Atlantic. Examples include Pico Island of Azores, Cape Verde Island. In addition, there are some coral islands as Bermuda and Volcanic Islands like, Ascension, Tristan da Cunha, St. Helena, Gough and others.

By and large, the Atlantic Ocean lacks in troughs and trenches which are far more characteristic of the Pacific Ocean. North Cayman and Puerto Rico are the two troughs and Romanche and South Sandwich are the two trenches in the Atlantic Ocean.

The Indian Ocean

The Indian Ocean is smaller than the Atlantic Ocean. Unlike the other two oceans, it does not open out northward into the Arctic Ocean; rather it is completely blocked on the north by Asia, and in this sense it can be considered only half an ocean. Its northern margin is very irregular. It is bounded on the west by Africa, and on the east by the island chain in Indonesia and Australia. In the south, it extends up to the continent of Antarctica from where it merges into the Atlantic and the Pacific. The average depth of the Indian Ocean is 4,000 metres which is comparatively lesser than that of other oceans. Marginal seas are also few. Find out their names from the map.

The floor of the Indian Ocean has fewer irregularities in comparison to the other two oceans. Linear deeps are almost absent. The only exception is the Sunda Trench, which lies south of the island of Java and runs parallel to it.

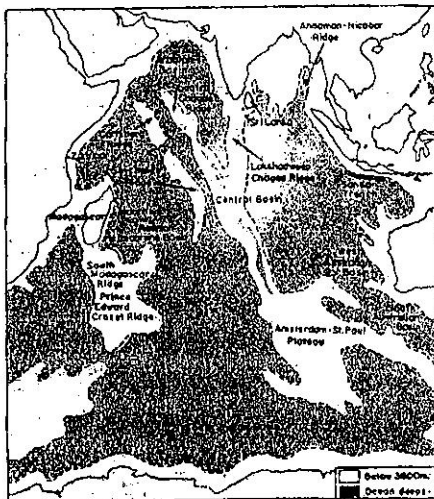


FIG. 15.5 The profile of the Indian Ocean basin

There are a number of broad submarine ridges on the floor of the Indian Ocean. Like the Atlantic Ocean, a prominent submarine ridge runs from Kanya Kumari continuously southward to Antarctica. It is situated in the middle and divides the ocean into two basins on either side. Unlike the Atlantic Ridge, it is wider and does not extend so near the surface. It is called the Lakshdweep-Chagos Ridge. In the north, the St. Paul Ridge in the middle and the Amsterdam St. Paul Plateau in the south, where it widens out considerably.

The central ridge is bifurcated into many small ridges which reach the coasts of Africa and India. Look at the map showing the Indian Ocean and notice that two minor and parallel ridges run north-westward. These are known as the Socotra-Chagos Ridge and the Seychelles Ridge.

Another ridge, known as the South Madagascar Ridge, runs southward from the Madagascar island. It widens in the

south, where it is called the Prince Edward Crozet Ridge. In the Bay of Bengal, another ridge called the Andaman-Nicobar extends from the mouth of the Irrawaddy the Nicobar Islands. The Carlsberg Ridge has been discovered by recent surveys and it divides the Arabian Sea into two parts.

The central and other ridges divide the Indian Ocean into many basins. Chief among them, are the Central Basin, Arabian Basin, South Indian Basin, Mascarene Basin, West Australian, and South Australian Basins.

Most of the islands in the Indian Ocean represent detached parts of the continental blocks. They surround this ocean on the north and the west. The Andaman and Nicobar, Sri Lanka, Madagascar and Zanzibar are important examples of this group. The Lakshdweep and Maldivé Islands, off the coast of south-western India, represent coral islands. The Mauritius and Reunion islands to the east of Madagascar are of volcanic origin. The eastern section of the Indian Ocean is almost free from islands.

EXERCISES

Review Questions

- Answer the following questions:
 - Name the most common features found on the ocean floors.
 - How have submarine ridges been formed?
 - Why are the ocean deeps or trenches believed to be of tectonic origin?
 - What are the main characteristics of submarine canyons? Name the best known submarine canyon in the world.
 - What are the four important processes that are responsible for a great variety of relief on the ocean floors?
- Discuss systematically the major submarine features, giving specific examples from all the three major oceans.
- Give one term for each of the following statements:
 - A gently seaward sloping surface extending between the shoreline and the continental slope.
 - A flat, nearly level area in the ocean, lying beyond the continental slope.
 - A predominantly organic deposit made by living or dead organisms that forms a mound or ridge-like elevation.
 - An electronic device used to determine and record water depth in the oceans.

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4. Make out correct pairs from the two columns :

- | | |
|--|----------------------|
| (i) A long, narrow range rising above the ocean floor. | (i) Submarine trench |
| (ii) A relatively small topographic feature of deep ocean floor ranging from 600 to 1,000 metres high and a few kilometres wide. | (ii) Guyot |
| (iii) A long, narrow and steep sided depression on the ocean bottom. | (iii) Bank |
| (iv) A flat-topped sea mountain. | (iv) Submarine ridge |
| (v) A more or less flat-topped elevation located in the continental margins. | (v) Abyssal Hill |

5. Distinguish clearly between the following terms :

- (i) Continental shelf and Continental slope
- (ii) Seamount and Guyot
- (iii) Shoal and Bank
- (iv) Submarine trench and submarine canyon

6. Check the accuracy of the following statements and correct them wherever they are inaccurate :

- (i) The ridge and basin topography is the characteristic of the ocean floors.
- (ii) Continents rise abruptly from the sea.
- (iii) Almost the entire marine food comes from the abyssal plains.
- (iv) The submarine ridges form the longest mountain system on the earth.
- (v) The continental slope joins the continents with the ocean floor.
- (vi) The Atlantic is the deepest of all oceans.
- (vii) The bottom relief of oceans influences navigation.

Finding Out

7. Find out some of the important discoveries made as a result of the International Indian Ocean Expedition.

Cartographic Work

8. With the help of the latest edition of a standard atlas, mark and label the important submarine features on the outline map of the Indian Ocean. Do not forget to include the latest discoveries made by I.I.O.E.

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CHAPTER 16

Ocean Waters and their Circulation

THE Oceans contain all but three per cent of the total amount of water on the earth. (The temperature and salinity are two important properties of the ocean water, which determine the movements of large masses of water, their characteristics and the types, and also the types of marine flora and fauna. Thus, temperature of the water of the oceans and its density, salinity and circulation are some important aspects in which geographers are specially interested.

Temperature of Ocean Waters

The temperature is an important physical property of the ocean water. It is an important factor in controlling the movements of large masses of ocean water and their characteristics. The type and distribution of marine fauna and flora also depend largely on the temperature of the water. The temperature of the surface water varies considerably throughout the world. Temperature below the surface also vary with depth. The temperature decreases according to the increasing depth of the ocean. In general, temperature in ocean waters varies from below -5°C to over 33°C .

Process of Heating and Cooling

There are two main processes of heating the ocean water, i.e. by absorption of radiation from the sun and by convection of heat through the ocean bottom from the

interior of the earth. The main processes of cooling the ocean water include: (i) back radiation of heat from the sea surface; (ii) convection; and (iii) evaporation. The interplay of heating and cooling processes determines the temperature distribution.

Distribution of Temperature on Oceans

The temperature and its distribution is determined by many factors such as the intensity and daily duration of solar radiation, the loss of insolation in the atmosphere, the amount of solar energy reflected back into the space from the surface, the characteristics of the surface such as salinity, density and the nature and amount of evaporation, the heat balance between the heat received and the heat transmitted back, heat transfer through evaporation and condensation, invasion of warm or cold air currents, local weather conditions, the location of submarine ridges, and lastly the location and shape of the sea.

In the oceans temperature of the surface water is not the same everywhere. It varies from one part to another. Water is hottest near the equator and the temperature gradually decreases polewards. The average annual temperature at the equator is 26°C , and at the latitudes of 20° , 40° and 60° , it is 23°C , 14°C and 1°C , respectively.

The isotherm of zero degree Celsius forms an irregular circle round the polar areas and moves towards the equator

during winter.

The apparent annual oscillation of the sun causes a seasonal change in the surface temperature. However, this change on the surface water of the oceans is

The isotherms over the oceans do not run parallel to the lines of latitudes. They are affected by the prevailing winds and the ocean currents. Thus, in the Tropical Zone, the western sections of the oceans are

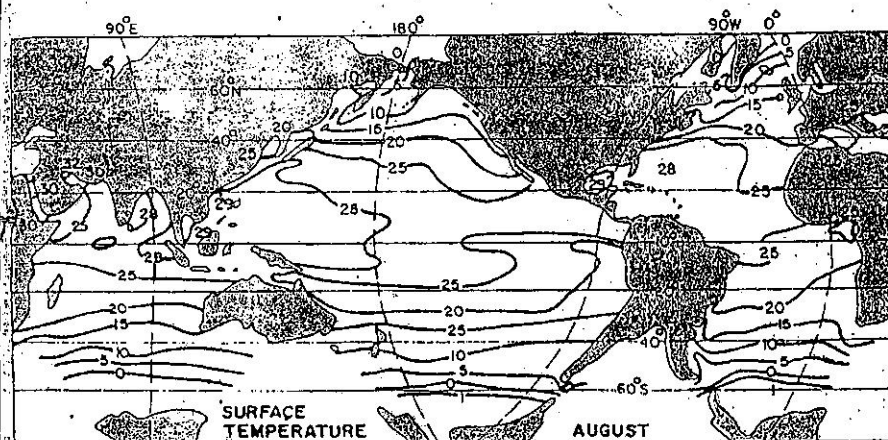


FIG. 16.1 Distribution of temperatures

comparatively less, than on the land surfaces.

The annual range of temperature is greater in the Atlantic than in the Pacific Ocean owing to the difference in their size. Similarly, the range is greater in the Northern Hemisphere as compared to the Southern because of the extensive continental blocks in the north.

Between the parallels of 20° north and south and south of 50°S . latitude, the range of temperature is about 5.5°C . The greatest ranges are, however, about 20°C in the north-western Atlantic near Newfoundland and about 25°C in the north-western Pacific near Vladivostok.

The highest temperatures are recorded in the enclosed tropical seas; for example, the average summer temperature of the surface water of the Red Sea is about 30°C .

warmer than the eastern sections owing to the influence of the trade winds. Similarly, the westerlies make the eastern sections warmer than the western in the Temperate Zone.

The surface waters of the Arctic Ocean as well as those around the margins of the Antarctic Continent remain permanently frozen and form extensive ice-fields. In winter, these ice-fields extend towards the equator and in summer they recede polewards. During summer, the marginal ice-fields break away and begin to drift towards the equator. The drifting ice-fields are called ice floes. Their height varies from less than a metre to slightly more than four metres. Some of the ice floes resembling ice sheets are found to be several kilometres in diameter.

Distinct from the ice floes are the huge

masses of floating ice known as icebergs. These huge masses of ice break from the tongue of a glacier or an ice barrier on reaching the sea. Icebergs float with their tips at least five metres above the water surface. It should be remembered that only about one-tenth of an iceberg remains above water, because the specific gravity of ice is only 0.9, whereas that of sea water, it is 1.025. Some of the icebergs tower about 90 metres above the level of the sea.

There are numerous icebergs in the North Atlantic, half of them originating from the glaciers in Greenland. In the North Pacific, these are rarely seen because of the narrow and shallow Bering Strait. Icebergs in the Southern Hemisphere are of enormous size. Some of them have been reported to be 60 kilometres in length. These tabular icebergs, looking like horizontal ice islands, originate from the edge of the Antarctic Ice Barrier. Icebergs are nature's way of desalinating sea water into fresh water.

Sub-surface Temperatures

The surface of the sea water receives the largest amount of insolation. As the rays penetrate the water, their strength is reduced by scattering, reflection and diffusion. Hence, there is a decrease in the temperature with the increasing depth. However, the rate of decrease in the temperature is not equal at all depths. Upto a depth of about 100 metres, the temperature of water is about the same as that of the surface, while it falls from about 15°C to about 2°C between the surface and a depth of 1,800 metres. The decrease between 1,800 and 4,000 metres is from 2°C to about 1.6°C. The rate of decrease is not the same at the equator and the poles. At the equator, it is greater than at the poles. Upwelling of water, sinking of dense surface water, regional higher

insolation, and submarine barriers influence variations in the sub-surface temperature. Of these, the most important factors are the cold and warm currents and the submarine topography.

Salinity

Sea water is brackish to taste. It contains a number of dissolved salts which result in the property of salinity. The salinity is expressed as the number of grams of dissolved salts in 1,000 grams of sea water. The average salinity of the sea water is about 85 per thousand or 35‰. It means that in one kilogram of sea water there are 35 grams of dissolved salts.

The ocean is the earth's greatest storehouse of minerals. It contains about 41 million tons of dissolved salts in every cubic kilometre of its water. Of the total salt contents found in sea water, sodium chloride constitute 77.7 per cent, magnesium chloride 10.9 per cent, magnesium sulphate 4.7 per cent, calcium sulphate 3.6 per cent, and potassium sulphate 2.5 per cent. Though, the total amount of dissolved salts is variable yet the relative proportion of the major elements is constant.

Much of the salt was perhaps dissolved in the water when the oceans were initially formed in the earlier part of the earth's history. Later on its quantity progressively increased as the rivers flowing over the land surfaces brought salts with them in solution. Thus, the salts in the sea water are ultimately derived from the earth's surface. Sea waves and rivers erode the crustal rocks and dissolve their constituents including salts and add them to the sea water.

Salinity determines, among other features, compressibility, thermal expansion, temperature, density, absorption of insolation, evaporation and

humidity. The amount of salinity also greatly influences the composition and movement of the sea water, the distribution of fish and other marine animals.

decreases both towards the equator and towards the poles. Near the equator the salinity is relatively low because of heavy rainfall, high relative humidity, cloudiness and calm air of the doldrums.

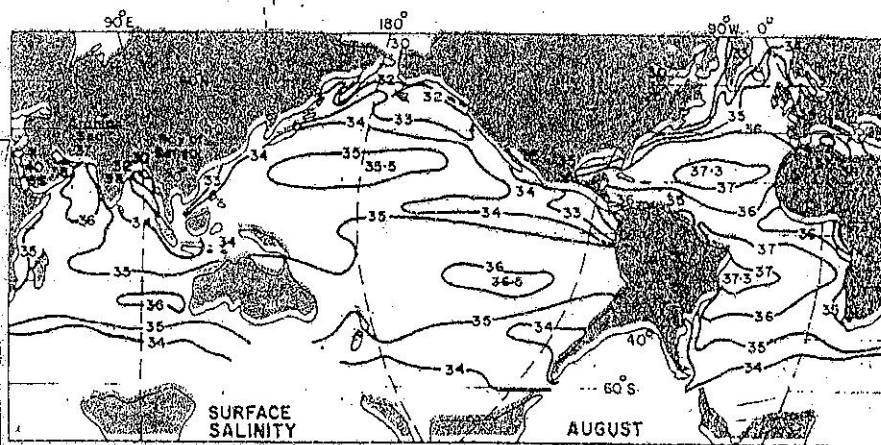


FIG. 16.2 Distribution of salinity

Distribution of Salinity

The distribution of salinity has two aspects: (i) horizontal, and (ii) vertical.

The amount of salinity varies from one part of the ocean to another. The salinity of the sea water is largely dependent on the difference between evaporation and precipitation. The variations are also controlled to a lesser extent by stream run off, freezing and melting of ice, atmospheric pressure, wind direction and movement of the sea water.

Broadly, the areas of the highest salinity are found near the Tropics. The explanation for this is that there is active evaporation owing to clear skies, high temperatures and the steady Trade Winds. In the Atlantic Ocean the salinity near the Tropics is about 37‰.

From the tropical areas, the salinity

The equatorial region of the Atlantic Ocean has a salinity of about 35‰, almost the same as the average of ocean water. In the polar seas, there is very little evaporation and this, coupled with the melting of ice* yielding fresh water, leads to a decrease in salinity usually ranging between 20‰ and 32‰. In this way the maximum salinity occurs between 20°N. and 40°N. and 10°S. and 30°S. latitudes. It decreases between 40° and 60° latitudes.

The differences in salinity are relatively small in the open seas but are well marked

*By contrast, water near freezing ice has more than the average amount of salt since the ice in the process of freezing, leaves the salt behind as a residue in the water. This cold and salty water sinks to the bottom. Thus, the heaviest water in the polar seas is found at their bottom. This is also true of other seas.

in partly or wholly enclosed seas. In the Baltic Sea, for example, the salinity decreases from 11‰ near the south Swedish coast to 20‰ near the head of the Gulf of Bothnia. In the Black Sea, which receives many rivers, the salinity is about 18‰ only. The Red Sea, on the other hand, owing to great evaporation and the absence of rivers has a salinity of more than 40‰.

The salinity of the inland seas and lakes is very high because of the regular supply of salt by the rivers flowing into them. Evaporation makes their water progressively more saline. The salinity, for example, of the Great Salt Lake (Utah in the United States), the Dead Sea and the Lake Van in Turkey is 220‰, 240‰ and 330‰, respectively.

The oceans and salt lakes are becoming more salty as time goes on because the rivers are constantly bringing more salt from the land, whereas evaporation is carrying away only fresh water.

Sub-surface Salinity

The salinity of sea water also varies with depth. In general, it decreases with the increasing depth. The decrease varies greatly with latitude. But the decrease is also influenced by cold and warm currents. The rate of decrease is highly variable in the North and South Atlantic Oceans. In high latitudes, salinity increases with depth. In the middle latitudes it increases upto about 35 metres and then decreases. At the equator, the surface salinity is lower.

Movements in the Oceanic Waters

The movement of ocean waters takes place in three different ways, viz., waves, currents and tides.

Sea water is mobile and responds readily

horizontally as well as vertically. The horizontal movement is both at the surface and sub-surface levels. These movements are due to variation in density from one part to another which results from the differences in the salinity and temperatures. Winds also provide a motive force for the horizontal movement of surface water.

Waves

Waves are a most conspicuous feature of oceans. They are oscillatory movements in water, manifested by an alternate rise and fall of the sea surface. These moving ridge-like curves on the surface of the sea have two parts: The top part of a wave is called its *crest* and the lower part between two waves is the *trough*.

Every wave has a wave length, velocity, height and wave period. *Wave length* is the distance between two consecutive crests. The time taken by two consecutive crests to pass any fixed point is known as the *wave period*. The vertical distance between a trough and a crest is the *wave height*. The main components of a typical wave are shown in Fig. 16.3. The velocity of a moving wave can be determined as follows:

$$\text{Velocity of wave (C)} = \frac{\text{Wave length}}{\text{Period (T)}}$$

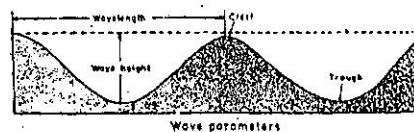


FIG. 16.3 Wave parameters

Waves are mainly produced by wind. When blowing winds impart their energy to the water in the form of frictional pressure on the smooth surface of the sea, waves are produced, once the sea surface is disturbed and its form is changed, there

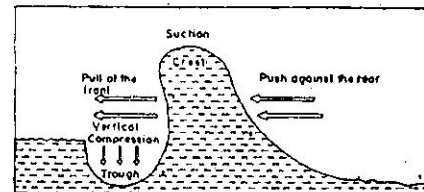


FIG. 16.4 Formation of wave

a push against the rear, suction over the crest, pull at the front and vertical compression in the trough (Fig. 16.4). The size and force of waves depend on three factors: (i) the velocity of the wind, (ii) the duration of the wind; and (iii) the distance over which the wind can blow unhindered (the fetch). Where the water is deep, the winds are fast, the winds blow over a long period, and the bottom does not interfere with the undulatory movement of the water, the formation of waves is unrestricted and full. For example, winds at a speed of 160 km per hour, blowing for about 50 hours and over a fetch of more than 1,600 km can produce waves of 15 metres height.

Waves represent a series of parallel crests separated by troughs. They travel in some definite direction over great distances. But it is only the wave motion that is transported, whereas the water particles remain at the same place. If a tennis ball is floated on the sea surface, it will move up and down and to and fro with the approaching series of crests and troughs, but it will not travel with the waves unless it is blown away by the wind.

There are three types of wind-generated waves: (i) Sea, (ii) Swell, and (iii) Surf. Several trains of differing wave lengths and directional movements of sea waves occur simultaneously in the oceans. It results into an overall irregular and chaotic wave pattern called the sea. Seas are complex

and variable in nature. As the waves move away from the winds that disturb the smoothness of sea surface they begin to move in an uniform pattern of equivalent period and height. These trains of waves are called *swells*. The pattern of swell is modified as they approach the shore. When waves reach shallow water near the shore, they crowd together, their height is increased and their slopes are steepened. Now, the lower part of each wave travels more slowly than the top owing to the friction offered by the bottom of the sea. The crest of the wave curls over and it breaks at the shore, forming a breaker. The broken mass of water dashes up the shore as *swash*. It then descends seaward as the *backwash*. These breaking waves in coastal regions are called *Surf*.

Besides wind produced waves, other types of seawaves include catastrophic waves, storm waves, internal waves and seiches. Catastrophic waves are sudden, violent and temporary and are caused by earthquakes, volcanoes or landslides in oceans. Storm waves are usually high resulting from strong wind action. Internal waves are formed at the boundary of two water layers having different densities, whereas seiches are stationary waves. Catastrophic and storm waves can cause great damage to coastal areas.

Currents

In terms of their significance, both in physical and human geography, the ocean currents are the most important of the movements in the oceanic water. The ocean current is the general movement of a mass of water in a fairly defined direction over great distances. Ocean currents can broadly be divided into two classes—the warm and the cool or cold currents. The warm currents are those which flow from the low latitudes in Tropical Zones

towards the high latitudes in the Temperate and sub-polar Zones. Similarly, currents flowing from the high latitudes towards the low ones are called cold currents.

The origin and nature of the movement of the currents are related to four sets of factors—(i) factors related to earth's rotation: gravitational force and force of deflection; (ii) factors originating outside the sea: atmospheric pressure, winds, precipitation, evaporation and insolation; (iii) factors originating within the sea: pressure gradient, temperature difference, salinity, density and melting of ice; (iv) factors modifying the ocean currents: direction and shape of the coast, seasonal variations and bottom topography.

As a result of the interplay of these factors, the currents reveal the following characteristics. In the Northern Hemisphere, the currents move to their right and in the Southern Hemisphere to their left. This is due to the effect of the Coriolis force or deflective force and follow

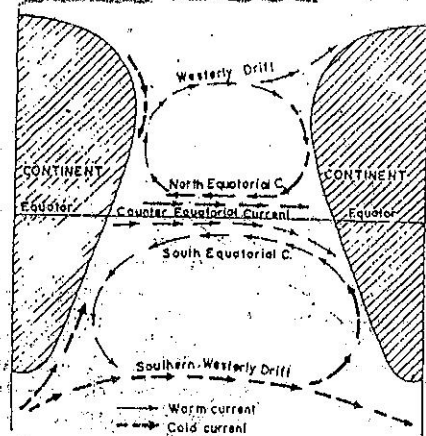


FIG. 16.5 General direction of ocean currents

the Ferrell's Law. A notable exception to the general scheme of circulation of ocean currents is, however, found in the northern part of the Indian Ocean. In this part the direction of currents changes in response to the reversal of the monsoon winds. Warm currents move towards the cold seas and cool currents towards the warm oceans. Cold dense waters near the surface occur in the middle latitudes on the western shores of the continents. Cold waters of lesser density move into the warmer oceans along the eastern coasts of higher latitudes. In the lower latitudes, warm currents flow on the eastern shores and cold on the western shores. In the higher latitudes, warm currents move along the western shores and cold currents along the eastern shores. Convergences along which the warm and cold currents meet and divergences from which they move out in different directions also control the currents. Finally, the shape and position of coasts play an important role in guiding the direction of currents.

The currents not only flow at the surface of the sea water but also underneath it. Such currents are caused by the differences in salinity and temperature. For example, heavy surface water of the Mediterranean Sea sinks and flows westward past Gibraltar as a sub-surface current.

Currents exert an influence on the climate of the bordering coastal regions. They affect temperature, humidity and precipitation. Cold currents bring plankton from the cold polar and sub-polar zones and thus increase the food supply for fish. As a result of this, fish thrive in large numbers in these areas. Important ocean highways follow the favourable currents, wherever possible.

Currents of the Pacific Ocean

In the North Pacific Ocean, the North

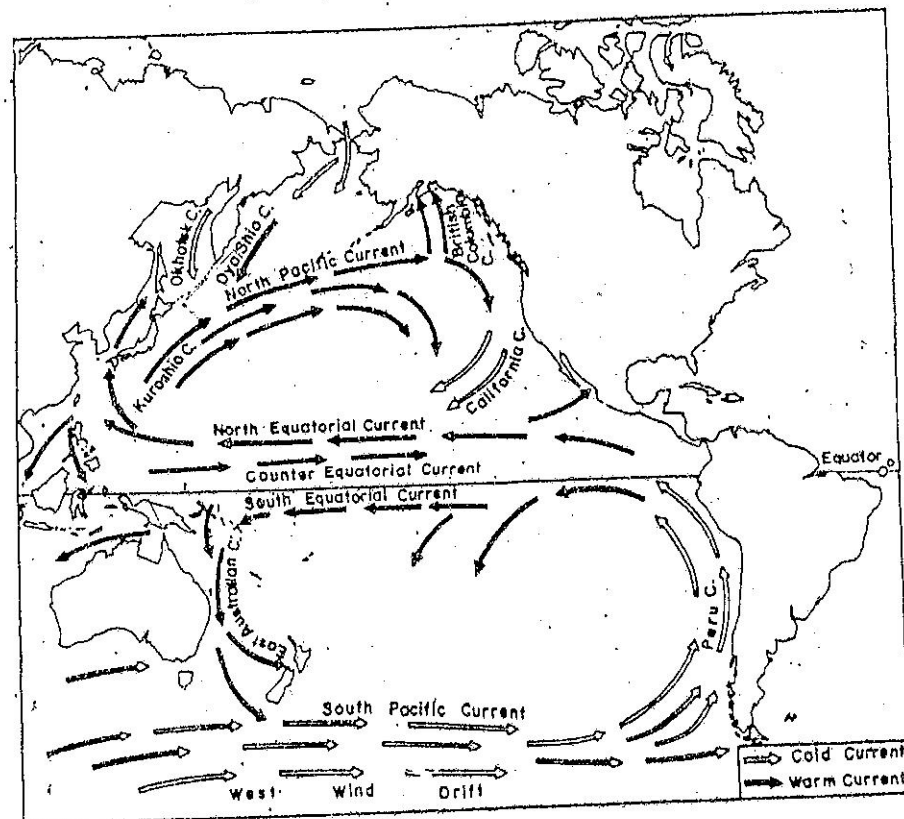


FIG. 16.6 Currents of the Pacific Ocean

Equatorial Current flows across the ocean from east to west, increasing in volume as it flows west. Starting from the west coast of Central America, it reaches the Philippine Islands in the Western Pacific Ocean. It then turns northwards along the Philippine Islands, Taiwan and Japan to form the Kuro-Siwo Current.

From the south-east coast of Japan, the current comes under the influence of prevailing westerlies and flows right across the ocean from west to east as the North

Pacific Current. After reaching the west coast of North America, it bifurcates into two branches.

The northern branch flows anti-clockwise along the coast of British Columbia and Alaska and is known as the Alaska Current. The water of this current is relatively warm as compared to that of the sea in this zone. The other branch of the North Pacific Current moves southward along the coast of California, as the cool current. It is known as the Californian

Current. It eventually joins the North Equatorial Current, which flows across 14,500 km of ocean under the influence of the trade winds, thus completing the cycle.

In the north of the Pacific, the Oya Siwo Current flows along the east coast of the Kamchatka Peninsula. It is a cold current. Another cold current in the North Pacific is the Okhotsk Current which flows past Sakhalin to merge with the Oya Siwo Current off Hokkaido. The Oya Siwo finally merges with and sinks beneath the warmer water of the Kuro Siwo.

In the South Pacific Ocean, the South Equatorial Current flows from east to west and turns southward as the East Australian Current. It then meets the South Pacific Current near Tasmania, which flows from west to east.

Reaching the south-western coast of South America, it turns northward as the Pery Current. It is a cold current which finally feeds the South Equatorial Current, completing the great circuit.

Between the North and the South Equatorial Currents, a current flows from west to east which is known as the Counter Equatorial Current. The North and the South Equatorial Currents cause accumulation of water in the western parts which disturbs the surface level. This difference in level makes the Counter Equatorial current flow eastward.

Currents of the Atlantic Ocean

The steady trade winds in north and south of the equator drive two streams of surface water westward. They are known as the North and the South Equatorial Currents. A return current called the Equatorial Counter Current flows from west to east between the two main Equatorial Currents in order to replace the removal of water from the eastern side of the ocean. It is

known as the Guinea Current off the West African coast.

The South Equatorial current bifurcates into two branches near Cape de São Roque (Brazil). Its northern branch reinforces the North Equatorial Current. Part of the combined current enters the Caribbean Sea and the Gulf of Mexico, while the remainder passes along the eastern side of the West Indies as the Antilles Current.

The branch entering the Gulf of Mexico is reinforced by a great bulk of warm ocean water driven by the trade winds and by the water brought by the Mississippi river. As a result, the water level in the Gulf rises as compared to that of the Atlantic Ocean. This difference in water level is compensated for by the current flowing out through the Strait of Florida and this branch is joined by the Antilles current. From the Cape of Florida, the combined current moves along the south-eastern coast of the United States and is known as the Florida Current up to the Cape Hatteras. Beyond the Cape Hatteras, up to the Grand Banks off Newfoundland, it is known as the Gulf Stream. The Gulf Stream is well defined in the deep waters.

From the Grand Banks, the Gulf Stream flows eastward across the Atlantic as the North Atlantic Drift. The main motive force for this current is supplied by the prevailing South-Westerly winds.

The North Atlantic current makes two main branches on reaching the eastern part of the ocean. The main current continuing as the North Atlantic Drift reaches the British Isles from where it flows along the coast of Norway as the Norwegian Current and enters the Arctic Ocean. The southerly branch flows between Spain and Azores as the cold Canary Current. This current finally joins the North Equatorial current completing the circuit in the North Atlantic. The Sargasso Sea lies

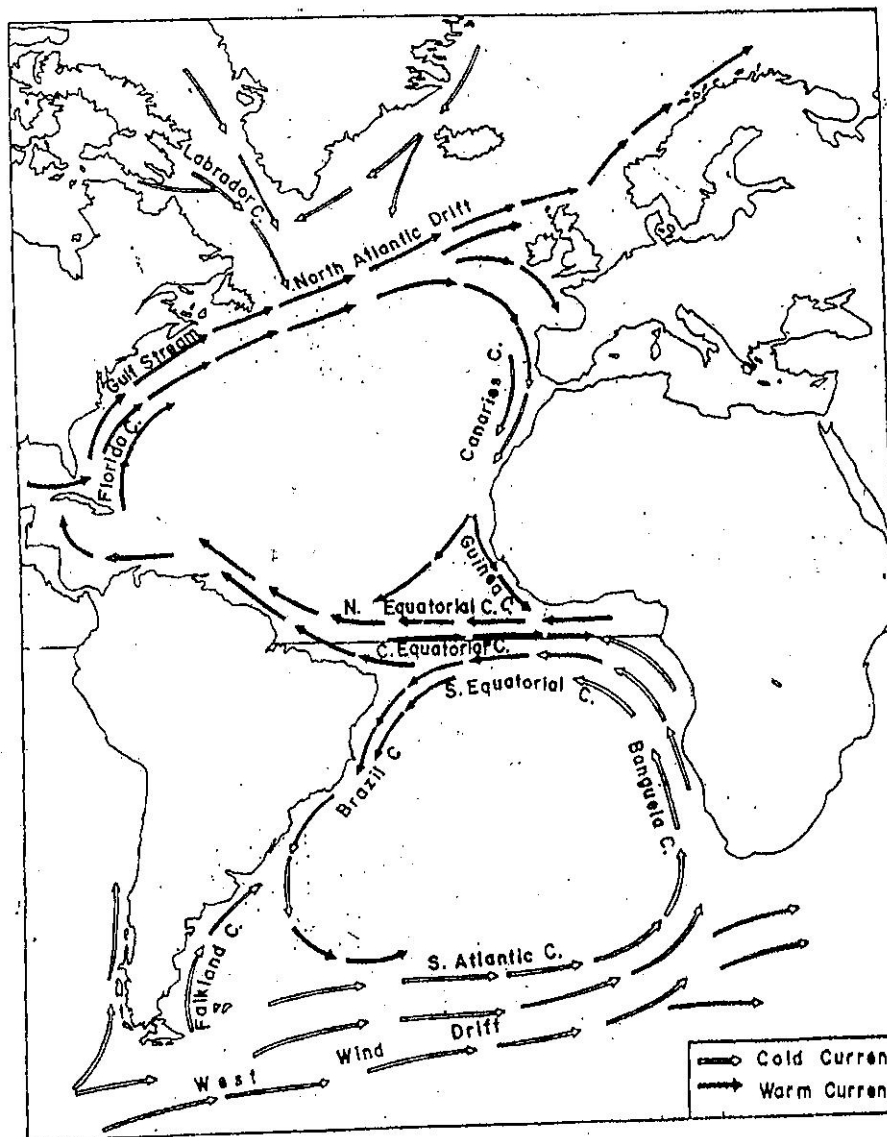


FIG. 16.7 Currents of the Atlantic Ocean

within this circuit which is full of large quantities of seaweed.

Two cold currents—the East Greenland current and the Labrador current flow from the Arctic Ocean into the Atlantic Ocean. The Labrador current flows along part of the east coast of Canada and meets the warm Gulf stream. The confluence of these two currents, one hot and the other cold, produces the famous fogs around Newfoundland. It is one of the most important fishing grounds in the world.

In the South Atlantic Ocean, the South Equatorial Current, flowing from east to west, splits into two branches near Cape de Sao Roque (Brazil). The northern branch joins the North Equatorial current, whereas the southern branch turns southward and flows along the south American coast as the Brazil Current. The Brazil current swings eastward at about latitude 35°S, to join the West-wind Drift

flowing from west to east.

Near the Cape of Good Hope, a branch of the South Atlantic current flows northward along the west coast of South Africa. It is a cold current and is known as the *Benguela Current*. It finally joins the south Equatorial current, thus completing the circuit.

Another cold current, known as the *Falkland Current*, flows along the south-eastern coast of South America from south to north.

Currents of the Indian Ocean

Being only half an ocean, completely land locked in the north, the characteristic current circulation of the Indian Ocean is different from those of the Atlantic and the Pacific Oceans. The currents in the northern portion of the Indian Ocean differ entirely from the general pattern of circulation. They change their direction from season to season in response to the

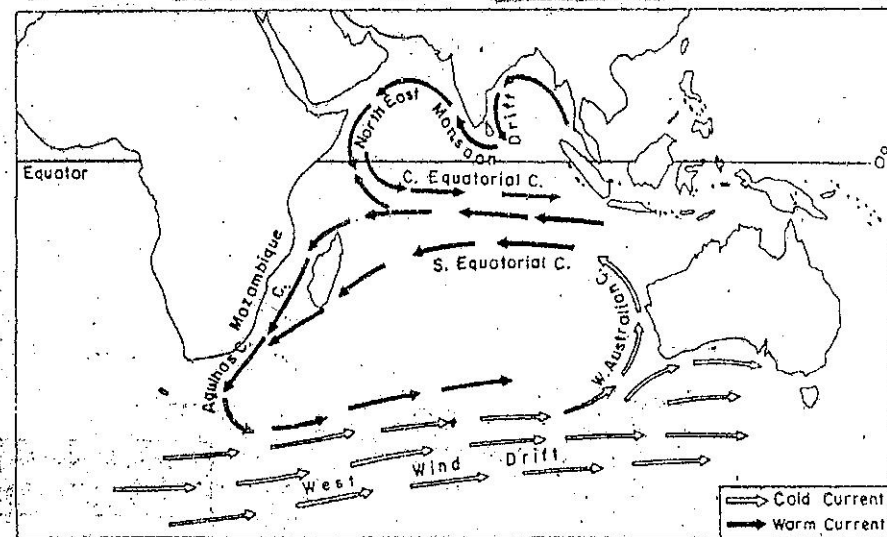


FIG. 16.8 Currents of the Indian Ocean (Winter)

seasonal rhythm of the monsoons. The effect of winds is comparatively more pronounced in the Indian Ocean.

In the northern section of the Indian Ocean, there is a clear-reversal of currents between winter and summer. In winter, the North Equatorial Current and the South Equatorial Current flow from east to west. A Counter Equatorial Current flows from west to east, between the two equatorial currents. The north-east monsoons drive the water along the coast of the Bay of Bengal to circulate in an anti-clockwise direction. Similarly, along the coasts of the lands bordering the Arabian Sea, an anti-clockwise circulation of currents develops (Fig. 15.8).

North East Trades. There is no counter Equatorial current at this time of the year. Thus, the circulation of water in the northern part of the ocean is clockwise during this season (Fig. 16.9).

The southern part of the Indian Ocean is perhaps less marked by the seasonal changes. The general pattern of circulation is simple and is anti-clockwise like that of the other southern oceans.

The South Equatorial Currents, partly led by the corresponding current of the Pacific Ocean, flows from east to west and turns southward along the coast of Mozambique in Africa. The current flowing through the Mozambique Channel is known as the *Warm Mozambique*

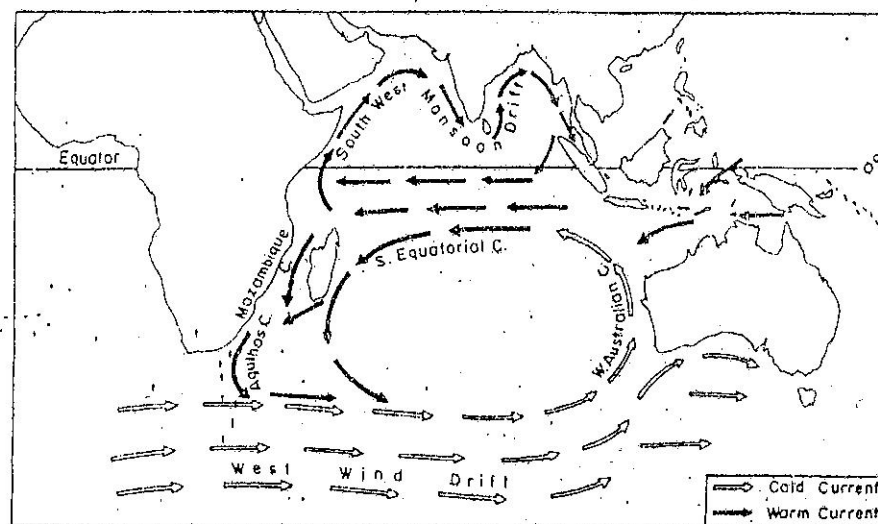


FIG. 16.9 Currents of the Indian Ocean (Summer)

In summer, a strong current flows from west to east which completely obliterates the North Equatorial current during this season. It is due to the effects of the strong south-west monsoon and the absence of the

Currents

Further southward, the Mozambique Current is joined by another branch of the South Equatorial Current flowing past Madagascar Island (Malagasy Republic).

After the confluence of these two streams, it is known as the Agulhas Current. It still continues to be a warm current till it merges with the West Wind Drift.

The West Wind Drift flowing across the ocean in the higher latitudes from west to east reaches the southern tip of the west coast of Australia. One of the branches of this cold current turns northwards along the west coast of Australia. This current, known as West Australian Current, flows northward to feed the South Equatorial Current.

Tides

Sea-water rises regularly twice a day at constant intervals. This periodic phenomenon of alternate rise and fall in the level of the seas is known as tides. Tides are produced as a gravitational interaction of the earth, moon and the sun. Tides can easily be measured. Tides are complex and they vary from place to place because of (i) the movement of the moon in relation to the earth, (ii) changes in positions of the sun and the moon in relation to the earth, (iii) uneven distribution of water over the globe, and (iv) irregularities in the configuration of oceans. The height of the tide at Okha is about 2.5 metres, while the tide in the Bay of Fundy between New Brunswick and Nova Scotia is the highest ranging between 15 and 18 metres.

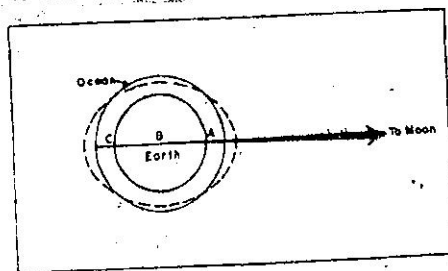


FIG. 16.10 Formation of tides

The gravitational interaction of the moon, the sun and the earth is responsible for the occurrence of tides. The sun by virtue of its bigger size should attract more; but owing to its greater distance from the earth it is unable to exert much influence. The moon on the other hand, though much smaller in size than the sun, is relatively very close to the earth, and is thus able to attract more than the sun. Hence, the moon exerts the strongest influence on tides. The tide producing force of the moon is twice as strong as that of the sun.

Suppose, the earth has a uniform depth of ocean water covering it, the attraction force of the moon is greatest at A, being nearest to the moon (Fig. 16.10). At B, the attraction of the moon is weaker and at C, it is the weakest. Thus, the gravitational attraction of the moon decreases from A to C. The ocean water at A, pulls away from the earth. Since the water is fluid and free to move, a tidal bulge in the direction of moon is produced. The solid part of the earth also bulges out but very slightly, a few centimetres at the most.

Note that a similar tidal bulge also develops in the oceans on the opposite side of the earth (Fig. 16.10 at C). This is because,

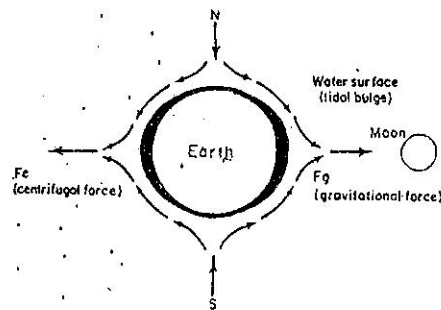


FIG. 16.11 Tides due to gravitational and centrifugal forces

the water on the other side of the earth is more affected by its tendency to be thrown out by the earth's rotation and revolution, or the centrifugal force. In fact, on the side of the earth nearest to the moon the attractive force is greater than the centrifugal force. The bulging on the other side is due to the excess of the centrifugal force over the attractive force (Fig. 15.11).

Tides do not rise to the same height every day. The relative position of the moon and the sun with respect to the earth is responsible for this variation in the height of tides. On the full moon and the new moon, the moon and the sun are almost in a line with the earth. Hence they exert their combined pull on the earth. Therefore, on these two days tides are highest and are known as spring tides (Fig. 16.12).

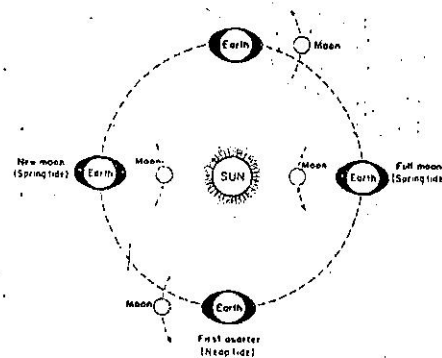


FIG. 16.12 Neap tides and spring tides

When the moon is at first and last quarter, the sun and the moon make a right angle at the earth's centre. The attraction of the sun and the moon tends to balance each other. As a result, tides with lowest amplitude occur. These tides are termed as neap tides.

Although tides occur twice a day, their interval is not exactly 12 hours. Instead,

they occur at regular intervals of 12 hours and 25 minutes. The moon revolves round the earth from west to east and completes one revolution in 29½ days. Therefore, at any place on the earth's surface, the moon does not appear crossing the meridian at the same hour every day as it moves a little eastward in 24 hours. It takes 24 hours and 50 minutes for the rotating earth to bring the same meridian vertically below the moon every day. Hence, high tides follow at intervals of 12 hours and 25 minutes. (Fig. 16.13).

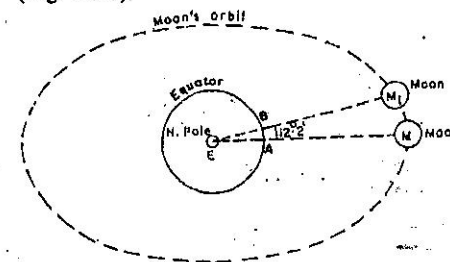


FIG. 16.13 The moon's revolution and the interval of tides

The earth would take another 48 minutes and 48 seconds to bring the point A exactly below M1. Actually, it requires an additional one minute and 36 seconds for the earth to bring the point A exactly below the moon as it has further moved a little during this small interval. This time lag of about 50 minutes thus explains the tide interval of 12 hours and 25 minutes, as tides occur twice a day.

Generally, tides occur twice a day. But Southampton along the southern coast of England, experiences tides four times a day. This peculiar phenomenon of four tides instead of two is due to the fact that the tidal waters come through the English Channel, as well as through the North Sea at different intervals.

Tides also occur in the arms of the seas known as gulfs. Gulfs with wide fronts

and narrow rears experience higher tides. The height of these tides may be ten metres or more. When a gulf is connected with the open sea by a narrow channel, water flows into the gulf at the time of high tide and comes out of the gulf at low tide. This movement of water, inward and outward, is known as tidal current.

When a tide enters the narrow and shallow estuary of a river, the front of the tidal wave appears to be vertical owing to the piling up of the water of the river against the tidal wave and the friction of the river bed. This steep-nosed tide crest looks like a vertical wall of water rushing upstream and is known as a tidal bore. The favourable conditions of tidal bores

include strength of the incoming tidal wave, slope and depth of the channel and the river flow. In India tidal bores are common in the Hooghly river.

Tides generally help in making some of the rivers navigable for ocean-going vessels. London and Calcutta have become important ports owing to the tidal nature of the mouths of the Thames and the Hooghly, respectively. Tides also clear away the sediments brought by the rivers and thus retard the process of delta formation. The tidal force may also be used as a source for generating electricity. For example, France and Japan have power stations which convert tidal energy into electricity.

EXERCISES

Review Questions

1. Answer the following questions :

- What factors control the horizontal and vertical distribution of temperature in the oceans?
- How is salt formed in the oceans?
- Why does the salinity of sea-water differ from place to place?
- Name the main types of wind produced waves and explain their modes of origin.
- Discuss the general characteristics of the ocean currents.
- Why do currents in the North Indian Ocean change their direction in summer and winter?
- How are tides caused?
- Why are the tides delayed everyday by 50 minutes?

2. How are ocean currents caused? What four sets of factors determine the nature and origin of ocean currents? Give concrete examples to illustrate your answer.

3. Discuss salient features of the ocean currents of the Atlantic Ocean with special reference to the Gulf Stream.

4. Give one term for each of the following statements :

- Floating or stranded masses of ice at least five-metres high above the level of the sea.

- Index of the amount of total dissolved solids in sea-water.
 - An oscillatory movement in a body of water manifested by an alternate rise and fall of the surface.
 - The breaking waves in a coastal region.
 - Currents flowing from low latitudes to high ones.
 - A vertical wall of tidal waters moving upstream in the river channel.
5. Distinguish clearly between the following terms :
- Ice-floes and Ice bergs.
 - Swell and Surf.
 - Swash and Backwash.
 - Spring tides and Neap tides.
6. Choose the correct ending for the following statement :
- The counter equatorial currents flow from west to east
- in order to compensate for north and south equatorial currents.
 - in sympathy with the earth's rotation from west to east.
 - as a result of Ferrel's Law.
 - because of the trades flowing from the tropics towards the equator.

Finding Out

7. Find out how salt is obtained from oceans, salt lakes and mines, if any in India. Collect also the relevant statistics.

Cartographic Work

8. (i) Compare the maps showing currents and planetary winds. Write a note on Ferrel's Law giving examples from both the maps.
- (ii) On a world map show cold currents and west coast tropical deserts; confluence of warm and cold currents and fishing grounds.

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CHAPTER 17

Marine Life and Deposits

THE marine environment has a large variety of flora and fauna. It is characterized by complex and intricately interdependent organic systems. The intensity of light, depth, currents, nutrients and dissolved gases are some important factors which control life in the oceans.

The marine environment is divided into two principal realms: *pelagic* and *benthic*. The former refers to the open ocean environment and includes the entire mass of water, while the latter refers to that part of the ocean bottom which is populated by organisms. The pelagic realm is further divided into the *neritic province* and the *oceanic province*. The two provinces are separated by the edge of the continental shelf. The neritic province is of greatest importance to marine life in general. It has a depth of about 200 metres and is the most populated area in the ocean by the marine life. It is characterized by shallow depth, receives most of the light, has low salinity, less turbulent motion and more of plant nutrients. It is the natural habitat of fish.

The oceanic province has a depth of more than 200 metres. It has an upper lighted zone and a lower dark zone with their boundary at a depth of 200 metres. The oceanic province is characterized by great geographic distribution, unmatched ranges of depth and relatively uniform temperature and salinity distribution. The

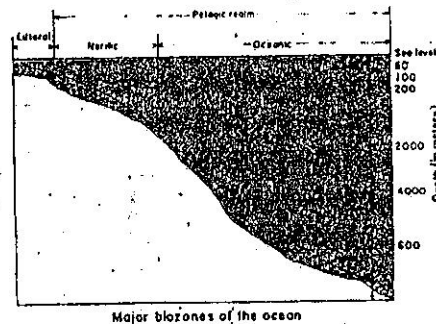


FIG. 17.1 Major biozones of the oceans

water in the oceanic province is clear and has no sediment of terrestrial origin.

The benthic realm is further sub-divided into littoral and deep sea zones. The two zones are separated by a depth of 200 metres. The littoral zone is characterized by the high and low tide level. Here primary food for animals is available in plenty. Isopods, gastropods, crustaceans and fishes live here.

The deep-sea benthic zone extends from depths of 200 metres to the deepest trenches. It is characterized by uniformly low temperatures, 5° to 1°C and persistent darkness. On the whole, the population of organisms decreases with the increasing distance from the coast. Most organisms in the deep-sea zone are carnivorous, living on the organic debris of dead organisms of the upper zone.

Modes of Marine Life

The marine plants and animals can be classified into three categories on the basis of their modes of locomotion and habitats: plankton, benthos, and nekton.

Plankton

Plankton are floaters or wanderers which have no means of self-propulsion. They are carried passively by currents. Most of them live in shallow water where they absorb sunlight and mineral nutrients. The majority of the plankton are microscopic in size but there are notable exceptions such as jelly-fish and brown algae or sargassum. Plankton are both phytoplankton (plant plankton) and zooplankton (animal plankton). Diatoms make up a large percentage of plankton. These are the most common single-celled microscopic plants usually covered with siliceous matter. They flourish rapidly in the cold water of the sub-Arctic and Antarctic regions. They are brought by cold currents to the temperate zone, where they float on the surface of the open oceans. Diatoms form the chief food of the fish and many sea animals. Zooplankton are larger and more complex in character than phytoplankton. Jelly-fish, arrowworms and small crustaceans are notable zooplankton. They live under varying conditions of temperature, salinity, currents and light.

Benthos

Benthos are organisms that live on the ocean floor. Benthos comprise both the mobile and the immobile. Lobsters, crabs, snails, burrowing calms and the worms which crawl or bounce on the sea-floor are examples of mobile benthos. The immobile benthos include plants like seaweeds and eelgrasses and animals like corals, sponges, barnacles and oysters.

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They are firmly attached to the sea-floor and are permanently stationary or fixed. Most benthos are found in shallow waters where sunlight reaches the bottom. Only a few of them are found in the deep oceans.

Nekton

Nekton are the swimming organisms and include fishes, whales, dolphins, porpoises and other animals. Nekton feed primarily on zooplankton live below the surface where food is plentiful. Many plant-eating nekton come on the surface only at night to feed on plankton. Nekton always move from place to place and from one depth to another in search of food and for breeding. Some move in cold water and others either in warm water or in the entire ocean. Nekton are an advanced form of animal in relation to plankton and benthos. Dolphins and porpoises are among the most intelligent animals of the world. Dolphins have been successfully trained in some parts of world to carry messages, mail and tools from one place to another.

Marine Vegetation

The marine vegetation is characterized by a limited variety. It consists chiefly of primitive plant forms which include various types of seaweed, technically known as *algae*. Advanced forms of plants are virtually absent from the ocean.

Algae are primitive plants in which the body shows little or no differentiation of vegetative organs. There is no true root, stem or leaf. Algae contain chlorophyll and are capable of photosynthesis. The larger algae occur on rocky reefs in bands, some distance away from the shore. The smaller algae grow on other plants and animals. The algae growing on plants is called the *epiphytic* and those growing on animals is known as *epizoic*. The algae are

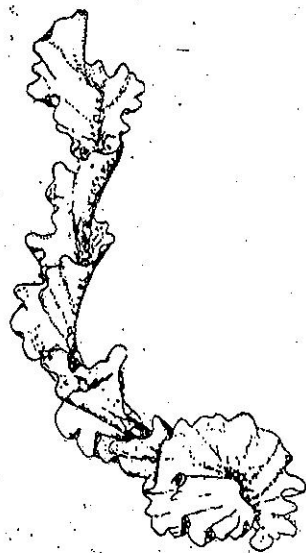


FIG. 17.2 Green Algae—Sea lettuce

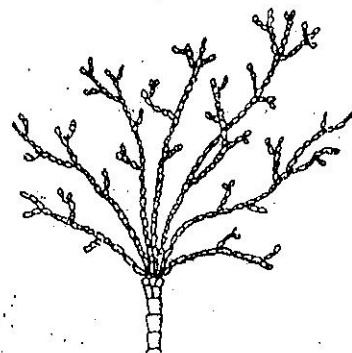
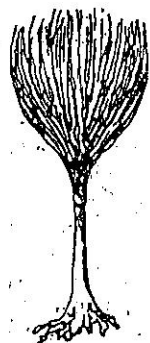
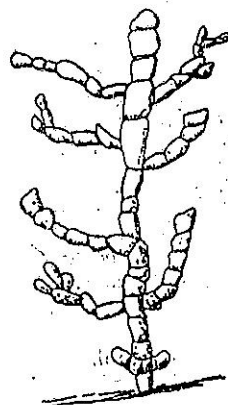
FIG. 17.3 Green Algae—*Halimeda*

FIG. 17.5 Red Algae—Irish moss

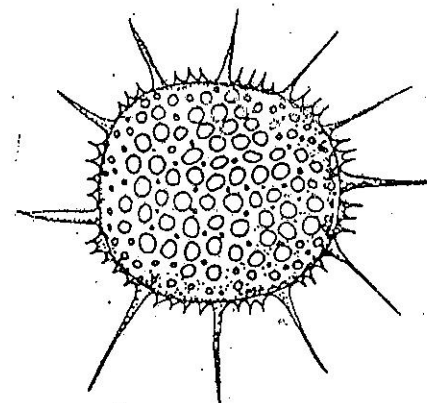
FIG. 17.4 Green Algae—*Neptune's shaving brush*FIG. 17.6 Red Algae—*Corallina*FIG. 17.7 Brown Algae—*Sargassum* species

beautifully coloured. Most common among them are blue-green, green, red and brown.

Of these, the brown algae is the most advanced type of algae and include familiar forms such as kelp and sargassum. Some brown algae such as *macrocystis* and *nerocystis* grow over 50 metres high. The Sargasso Sea of the North Atlantic Ocean derives its name from Sargassum. Brown algae are an important ocean resource for iodine and potash. Note some of the interest forms of marine vegetation below:

Marine Animals

The marine animals are more diversified than plants in terms of shape, size, and form. They are also more wide-spread in terms of depth. Many of them, however

FIG. 17.9 *Radiolarian*

live together in limited specific areas. As the marine animals do not depend upon sunlight for their survival, they are able to live at great depths where there is permanent darkness. These are the major

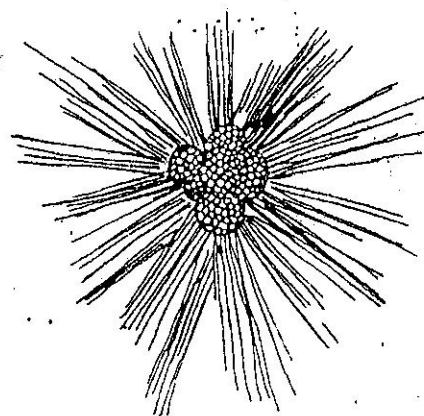
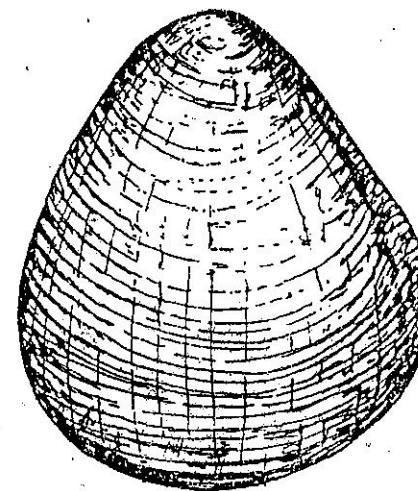


FIG. 17.8 Foraminifers

FIG. 17.10 *Brachiopod*

groups of marine animals. *Sarcodina* (foraminifers and radiolarians), *Poriferans* (sea sponges), *Coelenterates* (corals and jelly-fish), *Echinoderms* (star-fish, sea urchins and sea lilies), *Mollusc* (gastropod, clam and octopus), *Brachiopods* (lampshells), *Bryozoans* (moss animals), *Ctenophores* (gooseberries and comb jellies). *Marine Worms* may be classified into three groups: flat worms, arrow worms and segmented worms. *Arthropods* group of animals include crabs, lobsters, shrimps and hampacks. Lastly, there are about 25,000 species of fish and 50 species of sea snakes.

Corals

The coral is a kind of calcareous rock chiefly made of the skeletons of minute sea organism called polyps. These tiny organisms extract calcium salt from sea-water to build hard skeletons to protect

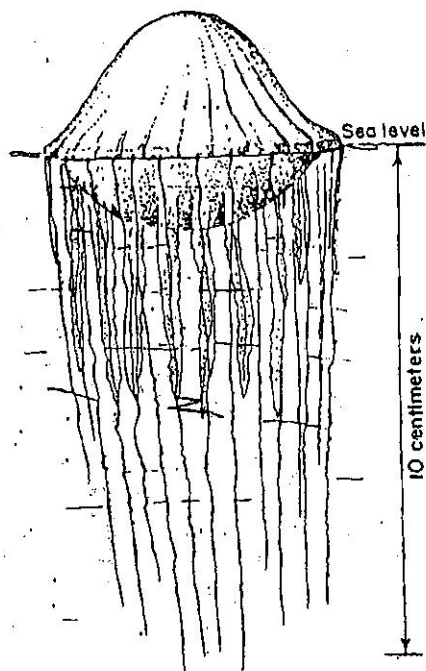


FIG. 17.11 A jelly-fish

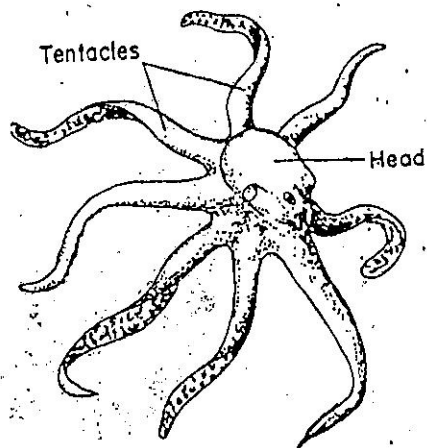


FIG. 17.12 Octopus

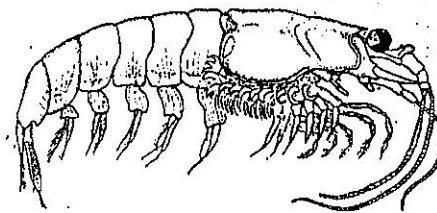


FIG. 17.13 A typical mollusc—Nautilus

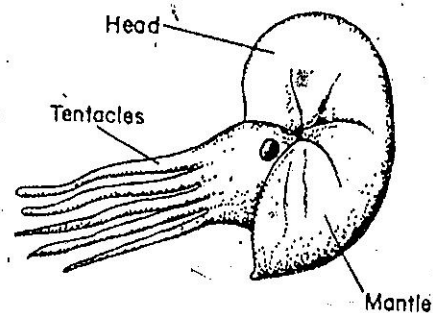


FIG. 17.14 The crustacean Euphausia Superba

their soft bodies. The tube-like skeletons extend upward and outward as the old polyps die and new ones are born. There are about 2,500 species of coral polyps. They live mainly in colonies which remain fastened to the rocky sea-floor. When one generation of polyps dies, fresh structures are built upon the old skeletons by a new generation. In due course of time, a great mass of coral reef is formed. The masses of cemented skeletons form hard calcareous rocks which vary in colour and form, depending upon the species forming them. Besides polyp, millions of small plants (algae) deposit calcium carbonate and thus contribute to the building of coral rocks. The progressive growth of corals from submarine topographic features appears in various forms in course of time above the surface of the sea. Corals are generally found in Tropical Seas between 30°N. and

30°S. Coral polyps need for their growth a temperature of about 20°C. They live at depths of almost 45 to 55 metres where sunlight is in abundance. Polyps thrive well in clear salt water. Both fresh water and highly saline water are harmful to the growth of the polyp. They avoid the delta regions. An adequate supply of oxygen and microscopic marine food known as plankton is essential for their existence and growth. As the food supply is more plentiful on the seaward side of a growing reef, coral grow on the seaward side more rapidly.

Three types of coral features have been recognised on the basis of their characteristics and mode of occurrence—(i) fringing, (ii) barrier, and (iii) atoll.

Fringing Reef

The fringing reef is a coral platform attached to the coast of a continent or an island. Sometimes, there is a lagoon or a shallow channel between the edge of the reef and the land. The fringing reef is a narrow belt and its width varies between 0.5 to 2.5 km. The fringing reef grows from the deep sea bottom. Its seaward side usually drops steeply into the sea. The surface of the reef is rough and is located above the level of low water. The waves

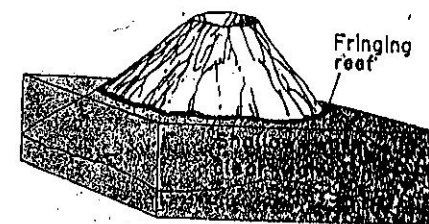


FIG. 17.15 Fringing Reef

deposit coral fragments and form a boulder zone called a reef flat. The coral polyps do

not extend outward because of the sudden and large increase of depth. The fringing reefs occur in new Hebrides Society Islands and off the southern coast of Florida. It is also found in the Gulf of Mannar near Rameswarum in South India.

Barrier Reef

The barrier reef is the largest of the three types. It may be several km wide and several hundred km long. The essential characteristic of this kind of reef is its distant location from the coast or the island. It is separated from the land by a comparatively broader and deeper lagoon. Lying almost parallel to the coast, it

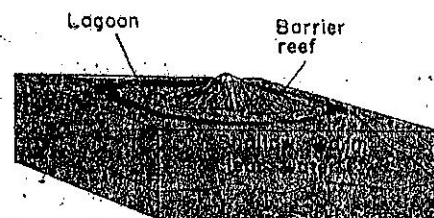


FIG. 17.16 Barrier reef

develops on a coastal platform. The barrier reef is generally very thick which extends below a depth of about 180 metres with very steep seaward slopes. Small channels usually cut across the barrier reefs connecting the lagoon with the open sea. The barrier reefs are formed by the accumulation of corals of various shapes, sizes through the ages. Their surface is covered with boulders, coral debris and sand. Generally, barrier reefs encircle islands in an irregular and broken ring.

The Great Barrier Reef off the north-east coast of Australia is the largest in the world. It is more than 1,900 km long and

about 160 km wide. The Great Barrier is 16 km from the coast at its nearest point and 240 km at the farthest. A vast complex of hundreds of separated reefs and island, the Great Barrier Reef is considered as a marine paradise. It attracts thousands of tourists every year from all over the world.

Atoll

The atoll is a ring-like reef which partly or sometimes completely encloses a shallow lagoon. A cross section of an atoll shows that the lagoon has a level floor but the outer edges of the atoll slope steeply. The lagoon has a depth of 80 to 150 metres in it. Generally, a large number of channels cutting across the atoll reef join the lagoon with the open sea. Atolls are located at great distances from the deep sea platforms. Favourable conditions are created at such places by the presence of

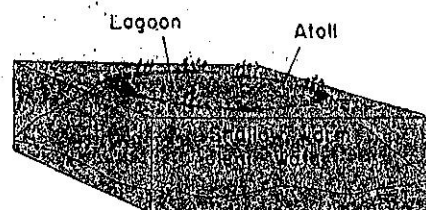


FIG. 17.17 Atolls

submarine features, the surface of which may rise to a level fit for coral growth. Such submarine features may include a submerged island, a volcanic cone, or a drowned island, owing to the positive movement of the sea level.

According to their nature atolls can be divided into three types (i) the true atoll with a circular reef enclosing a shallow lagoon with no island in it; (ii) an atoll which surrounds a lagoon with an island

in it; and (iii) a coral island or atoll island which is in fact an atoll reef, built by the process of erosion and deposition of waves with island crowns formed on them.

Atolls are far more common in the Pacific than any other ocean. The Fiji atoll and the Funafuti Atoll in the Ellice Island are well known examples of atolls. A large number of atolls also occur in the Lakshadweep Islands.

Marine Deposits

The ocean floor is almost covered with a blanket of sediments. This unconsolidated material lies over the bottom like a heavy mantle covering some of its features. It is just as soil covers the land surface of continents. The kinds of marine deposits differ a great deal from one part of the ocean to another. The marine deposits are the outcome of deposition of sediments due to continuous wearing of rocks along with the other material such as the remains of marine animals and plants. The study of marine deposits is very important for the understanding of the rocks exposed on the surface of the earth. These rocks were once laid down under the sea.

The marine deposits can be broadly divided into two main groups on the basis of their location (i) the deposits of the continental shelf and slope, and (ii) the deposits of the deep sea plains and deeps. The former consists mainly of material derived from the land and are often called *terrigenous deposits*. The latter are formed largely of the shells and skeletons of marine animals and plants. Such deposits are known as *pelagic deposits*. However, the distinction between the two groups is not absolute. The terrigenous deposits are not entirely composed of the rock material and the pelagic deposits are not entirely

made up of the remains of animals and plants. By and large, the terrigenous deposits are found near the continents.

The pelagic deposits mainly predominate in mid-oceans away from the continents.

However, with no sharp line of demarcation between them, the pelagic deposits may sometimes extend far up to the continental slope and the terrigenous deposits may be carried to the deep sea region.

Terrigenous Deposits

In general, the terrigenous deposits consist mainly of:

- (a) material derived from the wear and tear of the land;
- (b) the remains of animals and plants that live on the bed of the sea; and
- (c) volcanic material.

By far the greater part of the terrigenous deposits on the continental shelf and slope consists of the rock material. All kinds of rocks are continuously disintegrated into smaller fragments under the process of disintegration and decomposition. The loose material is carried down to the ocean by rivers. The process of disintegration and decomposition is not the same everywhere. It depends upon the character of rock and climatic conditions. The amount of disintegration depends upon the time for which rocks are exposed. The larger fragments of rocks are deposited near the shore. Whereas, the finer materials are carried far into the open sea. Thus, from the shore outwards there is a gradual decrease in the coarseness of the material. However, their outward extension is usually limited by the continental slope. The

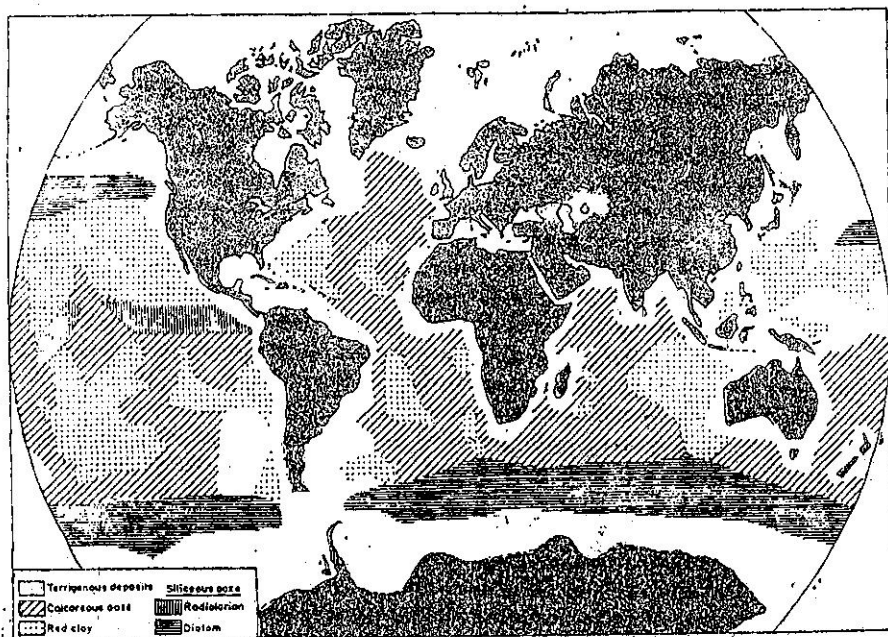


FIG. 17.1F Distribution of marine deposits

distance to which the rock material travels not only depends upon the size of the fragment but also on the strength of the waves and ocean currents.

On the basis of the size of the rock fragments, the sediments can be broadly classified into gravel, sand and mud. The finest material which is usually grouped under the general term mud, covers a large part of the continental shelf and of the slope beyond. Muds are of finer texture than the sands. They consist to a large extent of minute particles of various rock forming minerals, quartz being the most abundant. Murray distinguishes between the three main classes of mud based on the

colours of the sediments — blue mud, red mud and green mud.

Volcanic Deposits

In volcanic regions, the deposits of the continental shelf and slope consist chiefly of product of volcanism. The volcanic material which is being thrown out from a volcano is subject to chemical and mechanical weathering. It is then transported to the ocean by the action of running water and wind. These deposits again differ from the ordinary terrigenous deposits in the sense that they consist of the fragments of lava instead of quartz.

Organic Deposits

A great number of animals and plants live and grow on many parts of the continental

shelf. Their shells and skeletons settle down on the bottom and may form the greater part of the deposits. The organic shells and skeletons are changed into sand and mud by mechanical and chemical processes. These deposits contain only the calcium carbonate and thus they are different from the ordinary terrigenous deposits.

Pelagic Deposits

These deposits are most conspicuous on the deep sea plains and in the deeps covering about 75 per cent of the oceanic area. With the exception of fine volcanic dust, very little terrigenous material is carried beyond the continental slope. Wherever the supply of terrigenous mud is not much on the slopes, the deposits become more or less pelagic in type. The pelagic deposits are both organic and inorganic in nature. They consist partly of the remains of marine animals and plants and partly of the volcanic dust brought by the wind.

The organic group is chiefly represented by a kind of liquid mud which is known as ooze. The oozes contain shells of several kinds of organisms. In some oozes, the shell is made of calcium carbonate, while in others it is made of silica. Therefore, there are two main kinds of oozes: *Calcareous ooze* and the *Siliceous ooze*. These oozes are named after the predominant type of organisms.

The calcareous ooze is either the pteropod ooze or the globigerina ooze. The siliceous ooze comprises the diatom ooze and the radiolarian ooze.

In addition to the organic oozes, there is another type of deposit called the *Red Clay*. It consists mainly of inorganic material which is apparently of volcanic origin. Silicon and aluminium dioxide are the chief constituents. It also contains iron, manganese, phosphorus and radium. Red clay is the most widely spread pelagic deposits. It covers about 38 per cent of the total oceanic area. It covers more than half of the Pacific Ocean.

EXERCISES

Review Questions

1. Answer the following questions:

- (i) What are the two principal realms of marine environment?
- (ii) Mention the chief characteristics of the neritic province. Why is it of greatest importance to marine life?
- (iii) Why does the population of marine organisms decrease with depth?
- (iv) What are algae?
- (v) Why are marine animals able to live at great depths than marine plants?
- (vi) How are marine deposits formed?
- (vii) Classify the marine deposits on the basis of their location and origin.
- (viii) What are terrigenous deposits?

2. Write short notes on:

- (i) Plankton; (ii) Benthos; and (iii) Nekton.

3. Write a comprehensive essay on corals and coral deposits. Mention the essential conditions for their formation. Illustrate your answer with specific examples and diagrams.
4. Give a single term for each of the following statements:
 - (i) Floating or wandering forms of organisms with microscopic size, drifting passively with currents and tides.
 - (ii) Organisms that live on the ocean bottom.
 - (iii) Pelagic animals that are able to swim independently.
 - (iv) Collective term for planktonic plants.
 - (v) Collective term for animal plankton.
 - (vi) Marine deposits that are located on abyssal plain.
5. Distinguish clearly between the following terms:
 - (i) Pelagic realm and Benthic realm.
 - (ii) Neritic province and Oceanic province.
 - (iii) Terrigenous deposits and Pelagic deposits.
 - (iv) Fringing reef and Barrier reef.
6. Listed below are the important characteristics of the fringing reef, barrier reef and atoll. After going through the list, group them correctly under the respective coral type.

Finding Out

7. Search for coloured pictures and photographs of various kinds of marine plants, animals and coral formations. Only then would you realize how fascinating they are:

Find out what methods and tools are employed to collect samples of marine deposits from the ocean floor.

Cartographic Work

8. Locate coral islands, reefs and atolls on the map of Indian, Atlantic and Pacific Oceans. Write a brief report regarding their location in respect of latitudes, ocean currents, depth and proximity to land masses.
9. With the help of a standard atlas, show the distribution of the following marine sediments in oceans (i) Terrigenous deposits, (ii) Calcareous ooze, (iii) Radiolarian ooze, and (iv) the Diatom ooze.

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CHAPTER 18

Man and Oceans

THE oceans serve man in many ways both directly and indirectly. The chemical, biological and geological wealth of oceans is overwhelming. Man has exploited these resources for centuries. Oceans are also useful to man as a means of transportation and communication, and as a modifying factor in climatic environment. With the explosion of population, the dependence of man on oceans is bound to increase greatly.

Although the oceans hold great potentials for vast resource for the rapidly increasing population of the world, but they are not infinite. With the scientific knowledge, the man has improved his methods of exploitation of marine resources to a great extent. At the same time, he must also realise and try to control the exploitation keeping in view the place, time and quantity.

Oceans and Climate

Oceans exert an overwhelming influence upon the climate. They greatly influence the distribution of temperature and humidity over the earth's surface. Oceans act as savings bank for the solar energy. They receive deposits in seasons of excessive insolation and pay them back in seasons of want. Since the same amount of insolation heats the land surface faster than the water surfaces, the effect of oceans

on temperature and humidity of the atmosphere is very significant. Water not only heats up slowly than land, it also cools much more slowly than land. The enormous absorbing and liberating capacities of the oceans do not allow much extremes of temperature on the coastal areas and over the surface of the ocean. Thus, the range of temperature over the oceans and on the adjacent land is very insignificant. This major contrast between the effects of land and water on temperature conditions and their geographical distribution has resulted in two types of climates of the world viz., the *continental* and the *maritime* climates.

Ocean currents also help to modify the distribution of temperature along the coastal areas. The warm currents flow from the low latitudes towards the high latitudes and bring abnormally warm waters to cold areas. For example, the climatic conditions off the west and north-west coasts of Europe are governed by the warm water of the North Atlantic Drift. On the other hand, cold currents flow from the high latitudes to the low latitudes and bring water that is abnormally cold. In fact, ocean currents help in redistributing the heat over thousands of kilometres on the earth.

The oceans also control the distribution of pressure and prevailing wind system over the globe in a big way. The prevailing winds in turn determine the distribution

and the amount of rainfall over the earth. The oceans are, in fact, the main source from which our atmosphere derives its moisture. Rainfall which is so important to man, animal, plant life is the gift of oceans. Thus, the oceans are great regulators and stabilizers of climatic phenomenon over the earth.

Oceans and Food Resources

The oceans are a great source of food and other products of value to man. Man consumes fish, molluscs, crustaceans and many other edible forms of animal life. He also uses certain kinds of seaweeds to make foods. Besides food, many sea animals also provide oil, fur, leather, glue, cattle feed, and other useful products. Certain marine plants and animals are also used for making curative medicines. The most important factor about the marine biological resources is that they are easily available and inexhaustible. With the progress of human society, man has been increasingly depending on oceans for food and other useful things. Of all the marine resources, fish is the most abundant and widely used food.

Fish form a rich source of food and nutrition to man. Fish has been caught and consumed by man since the pre-historic times. For the world as a whole, fish now make up more than 10 per cent of the total animal protein food that man consumes. Herring, anchovy, pilchard, sardine, cod, salmon, tuna, mackerel, hake, haddock constitute the bulk of the world fish catch.

Today, fishing is a well developed industry in many parts of the world. Different fishing methods are used depending upon the behaviour of fish. The fishing methods range from primitive to most modern. Advanced fishing nations use more efficient methods including

trawling and drifting. Today all kinds of modern devices are employed in the fishing industry. Echo-sounders are used not only to detect shoals of fish below the surface, but also indicate the depth at which they swim. Modern fishing ships are fitted with computer-controlled sensors for locating fishing grounds. In addition, the modern fishing ships have huge fish processing factories. Advancements in refrigeration have made it possible to store for a longer period the huge catches at sea.

Important fishing areas of the world are concentrated in shallow waters of the continental shelves and over the banks in Northern Hemisphere. These areas provide the best supply of phytoplanktons—the food for fish. Five major commercial fishing regions have been identified: (i) North American Waters, (ii) North-Western European Waters, (iii) South American Waters, (iv) East Indian Waters, and (v) West Indian Waters.

Seaweed is being used for an increasing number of purposes as human and animal food, in cooking and in textile industry.

Oceans and Mineral Resources

Oceans are the storehouses of a large number of useful metallic and non-metallic minerals. Minerals occur both in solution and in suspension. Dissolved salts that are common in sea-water include common salt, magnesium and bromine. Other important minerals include petroleum, gas, manganese, phosphorite, sulphur, titanium, zircon, monazite, gold, platinum, diamonds, tin, iron, sand, gravel and many others. Of all the minerals found in the oceans, petroleum and gas are the most important. Offshore petroleum gas exploration and production has now become a global phenomenon. The main source of various minerals in the sea water is the land. The precipitation that falls on

the land carries vast amounts of mineral material to the oceans on its return journey. Ocean mining is far more expensive than land mining. It costs about twenty times more.

Oceans and Petroleum

The most important minerals produced from the sea are petroleum and gas, which alone accounts for more than 90 per cent of the total value of minerals obtained from the oceans. In view of recent energy crisis, the production of petroleum from offshore waters has increased considerably in the past two decades.

Petroleum is found mainly in the continental shelves and slopes and in small ocean basins. Some scientists estimate that about 20 per cent of the world's total reserves are deposited in offshore waters. At present the offshore waters of more than 75 countries are being explored for petroleum. The Bombay High is now an important oil producer of India. At present offshore petroleum comes from areas within 150 kilometres of the coasts and from depths of 2,000 metres. It is estimated that by the end of this century about 40 per cent of the world's oil production will come from the oceans.

Oceans and Energy

The energy resources of the oceans come in various forms: tidal force, geothermal energy and energy from ocean temperature differences.

Tides are the source of great energy. This energy is due to the rise and fall of the sea-water due to tide generating forces. The powerful tidal waves release large amounts of energy when they strike against the shore. The piston-like movement of tides can be tapped to run a generator and subsequently to produce

electricity. But there are difficulties in the use of tidal power because tides are irregular. However, a few tidal power stations are working successfully in the Commonwealth of Independent States, France and Japan.

The sea-water is capable of generating energy in another way. The principle underlying the generation of power from sea-water is based upon the difference in temperatures of surface and the sub-surface water. The water at the bottom of the ocean is cold and at the surface is warm. The water at the surface of sea in tropical region may be 25°C to 30°C, while the deep waters in the same locality are 5°C. This thermal gradient of 25°C is powerful enough to run a generator that would ultimately produce electricity. Floating generators have been designed in recent years to produce power from the difference in ocean temperatures. Such power plants are operating in Belgium and Cuba.

Geothermal energy in the oceans is associated with fracture zones and active volcanoes. Geothermal energy is especially promising for the generation of electricity in the coastal areas. At present the geothermal source of energy has already been developed in the U.S.A., Mexico and New Zealand.

Ocean Transportation and Trade

The oceans provide the most important means of natural transport to the man. As the oceans cover about 71 per cent of the total area of the earth's surface, they have proved to be an invaluable link among the continents and the nations of the world. Oceans not only provide the easiest means of transport but also the cheapest. Ocean transport is cheap because the nature provides free highways and the water is buoyant, needing less motive power. There are no obstructions such as gradients, which the land and inland water

transportation encounter. However, there are obstacles such as fog, icebergs, submerged reefs and storms. Moreover, oceans form a world highway which belongs to none and can be used by each and all. Therefore, the oceans as a highway has proved a boon for the international trade. Oceans are no more considered as barriers separating continents but provide natural links between them.

The ocean routes of the world depend on various factors: the great circle route or the shortest distance between two points over the globe; the facility for refueling at intermediate stations; the quantity of cargo and the presence of icebergs, submerged reefs, fog, storms and ocean currents. The North Atlantic Route which connects Eastern North America with Europe is the busiest ocean trade route in the world.

Oceans and Politics

An increasing importance of oceanic resources has been creating new grounds for disputes among nations. They have differed on territorial claims of sea-waters and on ownership of their resources. The politics has not left oceans untouched and Laws of the Sea are being perfected to avoid wars over the use of sea-water and all that it yields. High seas are to be kept free as common heritage of mankind.

A number of ocean highways, partially

closed seas and islands are getting global importance among superpowers of the world on account of their strategic military importance. The ownership of such sites for constructing air and naval bases in the sea has become the aim for increasing the sea power of great countries of the present-day world. Close to our country, the need for keeping Indian Ocean free from such developments is being realised by all the countries along its boundaries. The small or developing countries around this ocean are valuing the marginal and mid-ocean islands for making naval bases for guarding out coastline from the greed of the big powers. Defence of the oceans has thus become equally important for maintaining peace and for use of their resources by the countries adjoining them.

The future uses of the oceans will include desalination, deep sea oil exploration and production, deep sea mining of strategic minerals and production of power from the tides. One of the newer uses of oceans is to extract substances for vitamins and drugs from marine organisms for curing diseases. All this requires to keep oceans free from pollutions. The spilling of oil from large petroleum tankers, heavy concentration of toxic metallic contents, and addition of radio-active wastes from ships and nuclear explosions are to be checked to conserve rich marine life.

EXERCISES

Review Questions

1. Answer the following questions:

(i) List the various direct and indirect uses of oceans to man.

(ii) Why are oceans called great regulators and stabilizers of climate over the earth?

- (iii) Name important marine foods that man consumes today.
- (iv) Where are the major commercial fishing grounds of the world located?
- (v) What important minerals are found in the oceans? What is the main source of these minerals in the sea-water?
- (vi) How have the oceans proved a boon for international trade?
- (vii) In which countries has the tidal force been successfully harnessed?

2. Discuss systematically how oceans influence climate, giving specific figures and examples wherever possible.
3. Discuss in detail the significance of oceans for man. Give specific examples wherever possible.

4. Write short notes on:

- (i) tidal energy, and (ii) geothermal energy.

5. Make out correct pairs from the two columns.

- | A | B |
|--|------------------------------|
| (i) An edible form of segmented animal | (a) Crustacean |
| (ii) An edible form of soft-bodied animal covered by hard shells. | (b) Tidal energy |
| (iii) The busiest ocean route in the world. | (c) Mollusk |
| (iv) Energy associated with fracture zones and active volcanoes. | (d) North Atlantic Drift |
| (v) Energy due to the rise and fall of the sea water. | (e) The North Atlantic Route |
| (vi) The current which influences the climate of north-west coast of Europe. | (f) Geothermal Energy |
6. Which of the following statements contradict the contention that oceans are great 'regulators and stabilizer' of climatic phenomenon over the earth?
 - (i) Oceans receive deposits of solar energy in seasons of excessive insolation and pay them back in seasons of want.
 - (ii) The enormous absorbing and liberating capacities of the oceans do not allow much extremes of temperature on the coastal areas.
 - (iii) Oceans control the distribution of pressure in the upper atmosphere.
 - (iv) Ocean currents help to re-distribute heat over thousands of kilometres.

Finding Out

7. Find out all that you can about the modern devices employed in the fishing industry in the world. Also collect photographs of modern fishing ships, fish processing factories and computer controlled sensors.

Cartographic Work

8. (i) Show five major commercial fishing regions on the map of the world.
(ii) Show the important ocean routes on the map of the world.

Further Readings

- Bhatt, J.J. *Oceanography*. New York : D. Van Nostrand Company, 1978.
King, C.A.M. *Oceanography*. London : Edwin Arnold, 1975.
Sharma, R.C. and Vatal, M. *Oceanography for Geographers*. Allahabad : Chaitanya Publishing House, 1962.

UNIT V

The Biosphere

Cartographic Work

8. (i) Show five major commercial fishing regions on the map of the world.
- (ii) Show the important ocean routes on the map of the world.

Further Readings

Bhatt, J.J. *Oceanography*. New York : D. Van Nostrand Company, 1978.

King, C.A.M., *Oceanography*. London : Edwin Arnold, 1975.

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UNIT V

The Biosphere

CHAPTER 19

The Biosphere

The *biosphere* refers to that part of the earth in which all life forms exist. It is a shallow but extremely complex zone lying at or close to the interfaces between the three realms of the earth, i.e. the biosphere, the atmosphere and the hydrosphere. Since life of any kind is possible only in this layer, it is vital for us.

The organisms or life forms in the biosphere vary in size from minute bacteria to large whales or huge trees. All organisms may broadly be grouped under two categories—the plant kingdom and the animal kingdom. Under each category, there are several species. Human beings are just one of the species of the biosphere called the *Homo Sapiens*.

Ecosystems, Cycling of Matter and Flow of Energy

All organisms whether belonging to the plant kingdom or the animal kingdom interact with each other as well as with their physical environment. The study of the interactions between organisms and their environment is called *ecology*. The complex system of interactions between organisms and the physical environment in any unit of area is referred to as an *ecosystem*. It could be of any size from a small pond to the Amazon rainforest or the entire world.

What are the components of an ecosystem and how do they interact with each other? Let us understand it with the example of a small isolated woodland.

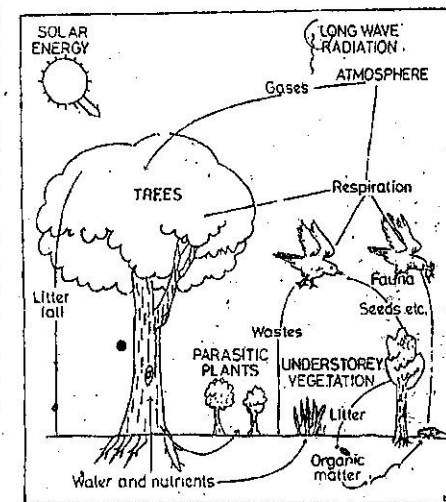


FIG. 19.1 The ecosystem of a woodland

The woodland consists of different kinds of plants and animals such as grasses, plants, trees, fungi, bacteria, birds and animals. All these organisms are closely associated. Some plants are parasites that feed on other plants. Similarly some animals are predators living off fellow animals. Many animals derive their food from plants. These relationships extend further. Plants derive nutrients and water from soil and air. When the plants and animals die, the mineral nutrients from the decayed plants and animals are released with the help of

countless organisms in the soil. These nutrients then return back to the soil from where they can again be taken up by the plants. Various components of the woodland thus interact with each other as well as with their physical environment. As such the ecosystem of the woodland consists of all kinds of life forms such as plants and animals (biotic or living component) and their physical environment such as soil, and water (abiotic or non-living component) with which they interact.

Irrespective of the size, the key features of an eco-system are the cycling of matter and flow of energy between various components. Matter and energy in the ecosystem are used to build, to reproduce and to maintain necessary internal energy level for sustenance.

All life forms are made of primarily three most abundant elements—carbon, hydrogen and oxygen. Other elements such as nitrogen, iron, sulfur, phosphorus and manganese are required only in small quantities. These elements are also called *nutrients*. Vast quantities of the major elements are found in large reserves in the atmosphere (e.g. carbon, oxygen and nitrogen) and in rocks (e.g. phosphorus, iron and sulfur). They enter the biosphere mainly through plants.

Matters consisting of elements and compounds move from one component of the ecosystem to another in a cyclic manner following distinct and consistent pathways. For example, carbon, oxygen, nitrogen and water, all move between the atmosphere, the lithosphere, the hydrosphere and the biosphere. While some of these matters complete their cycles in a very short time, some may be stored in certain forms where they are unavailable for use for prolonged period of geological times. Nevertheless, at any point of time they do not leave the total system of the planet earth. What makes these natural cycles operational?

We know that energy is required for any

work or movement. The ecosystem also functions due to energy transmission through its various components which makes natural cycles operational. The source of this energy could be traced back to solar radiation. In earlier chapter you have already read about latitudinal patterns of energy distribution and heat balance on the earth. They control the distributional pattern of life form on the earth and provide examples of energy flow in the abiotic component of the environment. Now we will read about energy flow in the biotic component of the environment.

The transfer of energy in the ecosystem takes place in a series of steps or levels, referred to as a food chain. Plants are the first level in the chain and are called the *producers*. They use light energy to convert carbon dioxide and water to produce carbohydrates and eventually to other biochemical molecules required to support life. This process of energy conversion is known as *photosynthesis*. At the next level of the chain are the *primary consumers*. These are the plant eating animals (herbivores) such as insects, mice and goat. At the third level are the secondary consumers, who feed on the primary consumers (carnivores) such as owl and lion. Some of the species are called omnivores because they are both herbivores and carnivores. Human beings come under this category. The *decomposers* (microscopic organisms and bacteria) feed on the detritus or the decaying organic matter derived from all levels. They help in recycling the mineral nutrients into the ecosystem and thus the food chain is completed.

A food chain is seldom as simple as described above because each organism may feed on a variety of food derived from different levels. Many simple foodchains intermingle with one another depicting complex interrelationships of organisms at each level and form a *food web*. Instead of unidirectional links one could

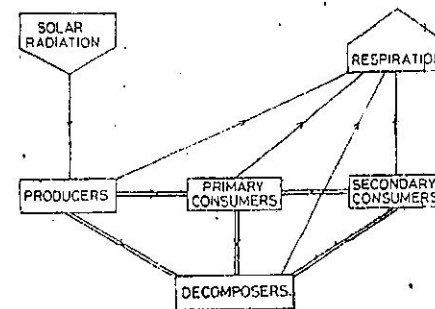


FIG. 19.2 The flow of energy through the foodchain

observe several interactions.

At each level of energy transformation, considerable amount of energy is lost. Much of this energy is expended by organisms in the form of body heat and respirations. Generally 10 to 50 per cent of the energy stored in organic matter at any level can be transferred to the next higher level in the chain. This explains why most of the food chains are limited to four or five levels and why animals at the higher level of the food chain have to depend over a larger area to obtain the required food. In other words each successive level within the ecosystem in an ascending order is by necessity much smaller. As a consequence we always find a very consistent pattern of the pyramid of numbers in all types of ecosystems. While the base of the pyramid consisting of the primary producers is large, there is a sharp decline in numbers at each successive level.

In a natural state, there is a perfect harmony between the various cycles and flow of energy establishing a *dynamic* and *fluctuating* equilibrium in any ecosystem. This is known as *ecological balance*.

Human Impact on the Ecosystem

Though human beings are just one of the species of the numerable life forms, they are much

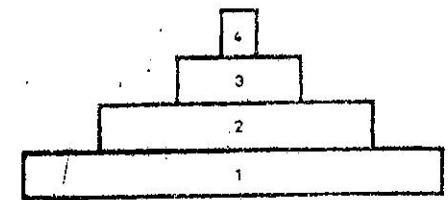


FIG. 19.3 A typical pyramid of numbers

1. Primary producers
2. Primary consumers
3. Secondary consumers
4. Tertiary consumers

more adept and omniscient member of the ecosystem than any other organism. With the help of science and technology they are becoming more and more capable of having a significant impact on plants and animals. They have been able to domesticate many plants and animals for greater human use. It meant changing the genetics of plants and animals so that the new desirable characteristics are passed on to succeeding generations. The effect of domestication is to replace the process of natural selection by those of human selection. Our agricultural crops and domestic animals are the results of this kind of environmental control.

The other significant impact could be seen by the way of introducing plants and animals to new areas crossing the physical boundaries on land and sea. Sometimes these introductions have been deliberate for the sake of food, aesthetic appeal, sport or any other necessity. But at times, these introductions have been accidental. Irrespective of the way of the introduction, occasionally these plants and animals find their new habitat free of competition. As a consequence, their growth rate is so fast that they outnumber many species soon and alter the environment drastically.

Hence they are considered an environmental threat.

Due to scientific and technological advancements, human interference with the natural environment has increased disproportionately in recent years. Ecosystems in many parts of the world have been modified or altered. For example, introduction of new irrigation projects in dry areas have resulted into salinization of soil and spread of water-borne diseases. Similarly, nature's self-building processes and natural cycles have often been disrupted due to human activities. For example, water gets purified in a natural way but it takes its own time. If the rate of polluting the water is higher than the rate of getting it cleansed in a natural way, the stage will soon be reached when it would be unsuitable for human consumption. Similarly land and air also get polluted. Due to rapid growth of population and fast industrial development, the amount of wastes disposed of in air, water and on land has increased tremendously. In recent years, environmental pollution has emerged as one of the major global problems because it damages the quality of environment extensively and thus affects the biosphere. For example, certain chemical substances present in air, water and food damage human health. Deterioration of the environment affects the whole plant and animal kingdom.

Another serious problem of the environment demanding immediate attention of human beings is the deterioration of natural resources. It refers to the reduction in the quality as well as quantity of the resources. Some of the resources such as air and water are renewable. Others such as minerals are non-renewable.

However, resources are renewable as long as environmental conditions are favourable. Careless use may destroy them to an extent that they may not be available to mankind in the near future. For example, wasteful use or pollution of water may create its scarcity. The problem is still much more acute with the non-renewable resources. Since their formation or concentration takes several thousand years, their over-exploitation may cause deprivation of such resources. For example, mineral oil once exhausted may not be available for human use in the near future.

Most of the environmental problems of the present-day world are essentially man-induced hence their solutions also lie in their hands. If we want the survival of the human race, we will have to learn to live in harmony with the environment. For this we have to avert deterioration, damages or destruction of the affected systems. Besides, checking pollution, we have to conserve our resources so that they could be stretched for a prolonged use. It is possible by substitution and recycling. For example, plastics are being widely substituted for metals in many applications. But we should remember that plastics are also synthesized from compounds which are themselves mineral resources—petroleum and coal. Besides, they also create pollution because their disposal is difficult. Hence careful selection from various alternatives is necessary. Several resources such as minerals can be recovered and used again in a process known as *recycling*. For example, scraps metal from the automobiles may be melted and used to make new items. However, much attention has not been paid to this aspect. It requires intensive research and development

EXERCISES

Review Questions

1. Answer the following questions:
 - (i) Why is biosphere important?
 - (ii) What is an ecosystem?
 - (iii) What makes natural cycles operational?
 - (iv) Why is conservation of natural resources necessary?
2. Distinguish between:
 - (i) herbivores and carnivores
 - (ii) biotic and abiotic components of the environment
 - (iii) producers and consumers
 - (iv) food chain and food web
3. Discuss human impact on the ecosystem.
4. Discuss the ways to check environmental degradation.

Finding Out

5. Collect clippings from newspapers for a week about environmental problem. Prepare a report discussing the nature of the problem and its extent, the geographical area and the possible reasons.

Cartographic Work

6. Prepare graphs showing the population growth, reserves and production of iron, coal and petroleum for the world (continentwise) from 1950 to 1980 at an interval of 10 years. Discuss the result.

Further Readings

1. Strahler, A.N. and A.H. Strahler, *Geography and Man's Environment*, New York John Wiley & Sons, 1977.
2. Oliver, J.E. *Physical Geography*, Duxbury Press, 1979.
3. Goudie, A. *The Nature of the Environment*, Oxford: Basil Blackwell Publishers Limited, 1984.

APPENDIX I

ANGLE OF INCIDENCE OF SUN'S RAYS AND DURATION OF DAYLIGHT

Latitude	September 21 or March 21		June 21		December 21	
	Duration of daylight	Angle of incidence	Duration of daylight	Angle of incidence	Duration of daylight	Angle of incidence
90°N	12 hours	0°	24 hours	23° 30'	0	0°
66° 30'N	12 hours	23° 30'	24 hours	17°	0	0°
50°N	12 hours	40°	16h 18m	63° 30'	7h 42m	16° 30'
23° 30'N	12 hours	66° 30'	13h 27m	90°	10h 33m	43°
0°	12 hours	90°	12 hours	66° 30'	12 hours	66° 30'
23° 30'S	12 hours	66° 30'	10h 33m	43°	13h 27m	90°
50°S	12 hours	40°	7h 42m	16° 30'	16h 18m	63° 30'
66° 30'S	12 hours	23° 30'	0	0°	24 hours	47°
90° S	12 hours	0°	0	0°	24 hours	23° 30'

APPENDIX II

CLIMATIC DATA FOR REPRESENTATIVE STATIONS OF DIFFERENT TYPES
(T = Temperature in Degree Celsius; P = Precipitation in Centimeters)

No.	Climatic Type	Station	Location	Altitude (in meters)	J	F	M	A	M	J	J	A	S	O	N	D	Annual	Range
1.	Tropical Rainforest	Singapore	1° 31' N 104° E	10	26.1	26.2	27.2	27.6	27.8	28.9	27.4	27.1	27.1	27.2	26.7	26.3	27.1	1.1
2.	Savanna	Quibha (Brazil)	13° 30' S 56° W	165	27.2	27.2	27.2	26.6	25.5	21.8	17.2	16.3	20.0	12.2	18.1	23.6	28.2	11.1
3.	Monsoon	Bombay (India)	19° N 73° E	11	24.4	24.4	24.4	26.7	28.3	30.0	28.9	27.2	27.2	27.2	27.8	27.2	25.0	5.6
4.	Desert	Jacobabad (Pakistan)	28° N 68° E	57	15.9	16.7	16.7	23.9	29.4	34.4	36.7	35.0	33.3	31.7	26.1	19.4	15.0	22.8
5.	Steppe	Salt Lake City (USA)	40° 46' N 111° 50' W	1280	-2.1	0.9	4.7	9.9	14.7	19.4	24.7	23.6	18.3	11.5	3.4	-0.2	10.7	26.8
6.	Mediterranean	Rome (Italy)	41° 52' N 12° 57' E	5	8.0	9.0	10.9	13.7	17.5	21.6	24.4	24.2	21.5	17.2	12.7	9.3	15.9	16.4
7.	China	Buenos Aires (Argentina)	35° S 58° W	25	23.3	22.8	20.6	16.1	12.8	10.0	9.4	10.6	12.8	15.6	18.9	21.7	16.1	13.9
8.	Marine West European	Berlin (Germany)	52° 28' N 13° 26' E	50	-0.5	0.2	5.9	9.0	14.5	17.7	19.4	18.8	15.0	9.6	4.7	1.2	9.5	19.9
9.	Taiga	Verkhoyansk (Russia)	67° 53' N 133° 23' E	137	-46.8	-43.1	-40.2	-33.5	-2.7	12.9	15.7	11.4	2.7	14.3	-35.1	-44.5	-15.2	62.5
10.	Cool east-coast	Quebec (Canada)	47° N 71° W	90	-12.2	-11.1	-5.0	2.8	10.6	16.7	19.4	17.8	13.9	6.7	-1.1	-8.9	3.9	31.6
11.	Continental	Novosibirsk (Russia)	53° N 83° E	156	-11.1	-9.4	-4.4	3.3	11.7	16.7	18.9	17.2	11.1	4.4	-2.2	-8.5	3.9	90.0
12.	Tundra	Barrow Point (Alaska)	71° 18' N 156° W	6	-28.3	-25.0	-22.6	-18.9	-6.1	1.7	4.4	3.9	-0.6	-8.9	-21.7	-26.1	-12.2	32.7
13.	Ice Cap	Mc Murdo Station (Antarctica)	77° 53' S 167° 00' E	2	-4.4	-8.9	-15.5	-22.8	-23.9	-24.4	-26.1	-26.1	-24.4	-18.8	-10.0	-5.9	-17.4	-22.2
14.	Alpine or Mountain type	La Paz (Bolivia)	16° S 68° W	3632	10.6	10.6	10.6	10.0	8.9	7.2	6.7	7.8	9.4	10.6	11.7	11.1	9.4	5.0